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Decision-Makers Guide in Solid Waste Management

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These criteria determine most decisions in the solid waste field. The cost criteria are among the most important to local managers, and therefore cost information is presented for as many of the issues as possible.

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Foreword

In solid waste management, as in other aspects of city administration, good decision-making is nearly synonymous with good city management. In the past, however, decisions regarding solid waste management have been based largely on intuition and local custom rather than on the experience of many communities and methodically developed information. To provide local officials with a broader basis for decision-making, the Office of Solid Waste Management Programs (OSWMP) of the U.S. Environmental Protection Agency developed the *Decision-Makers Guide in Solid Waste Management*. The guide draws on information which has been developed over the last 9 years from contractual efforts, demonstration grants, and in-house analyses.

The purpose of the guide is to help managers in municipal government deal with the problems of major concern in the field of solid waste management. It is not suggested that use of the guide will always lead to the best solutions but it can assist in placing the issues within a decision-making framework that is based on the latest available information. This is the second edition of the guide; OSWMP plans to publish updated versions regularly so that it will continue to reflect the rapidly changing field of solid waste management. Suggestions for improvements and other comments from readers are welcome.

While all parts of the Office of Solid Waste Management Programs contributed to the writing of the guide, the Systems Management Division was responsible for its planning and development. Special acknowledgment is made to Cynthia McLaren, the project officer responsible for coordinating the development of this guide for the Division, and to Emily Sano, who edited it. A list of OSWMP staff members who authored various sections of the guide appears on the following page.

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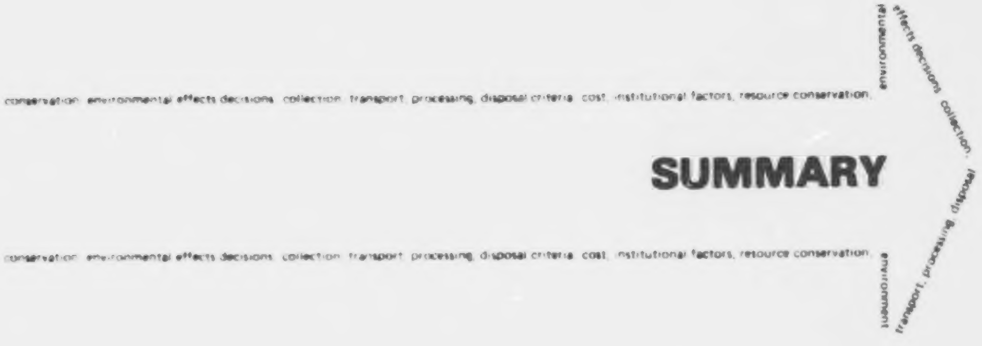
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SUMMARY

This guide presents the key issues of solid waste management in a decision-making context. It attempts to anticipate all of the important decisions which local government managers must make in the effort to develop and operate solid waste programs in a responsive, cost-effective manner. Each chapter presents an issue, describes the alternatives, gives the advantages and disadvantages, and concludes with a summary statement which may include an EPA recommendation on the issue.

CRITERIA FOR DECISION-MAKING

There are four basic categories of criteria by which decisions are made in the solid waste field: costs, environmental factors, resource conservation, and institutional factors. The key points in each of these categories are as follows:

- Costs
    - Operating and maintenance
    - Capital (initial investment)
- Environmental factors
    - Water pollution
    - Air pollution
    - Other health factors
    - Esthetic considerations
- Resource conservation
    - Energy
    - Materials
    - Land
- Institutional factors
    - Political feasibility
    - Legislative constraints
    - Administrative simplicity

These criteria determine most decisions in the solid waste field. The cost criteria are among the most important to local managers, and therefore cost information is presented for as many of the issues as possible. Environmental criteria are most important in the areas of waste storage and disposal because these functions represent prolonged exposure of wastes to the environment. Collection and processing are usually short-term operations and therefore do not cause major environmental problems.

Resource conservation is a criterion just beginning to be considered seriously by local governments as citizens become increasingly conscious of this issue.

Certain institutional factors are sometimes the most important criteria, although not as easy to quantify or deal with as costs. Also, these criteria are less easily generalized, so each manager has to identify the institutional criteria peculiar to his locale. Nevertheless institutional factors should always be of major concern to the decision-maker since they frequently prevent a decision from being made or eliminate an alternative.

DECISIONS TO BE MADE

Solid waste management is concerned largely with four major functions: collection, transport, processing, and disposal (Figure 1).

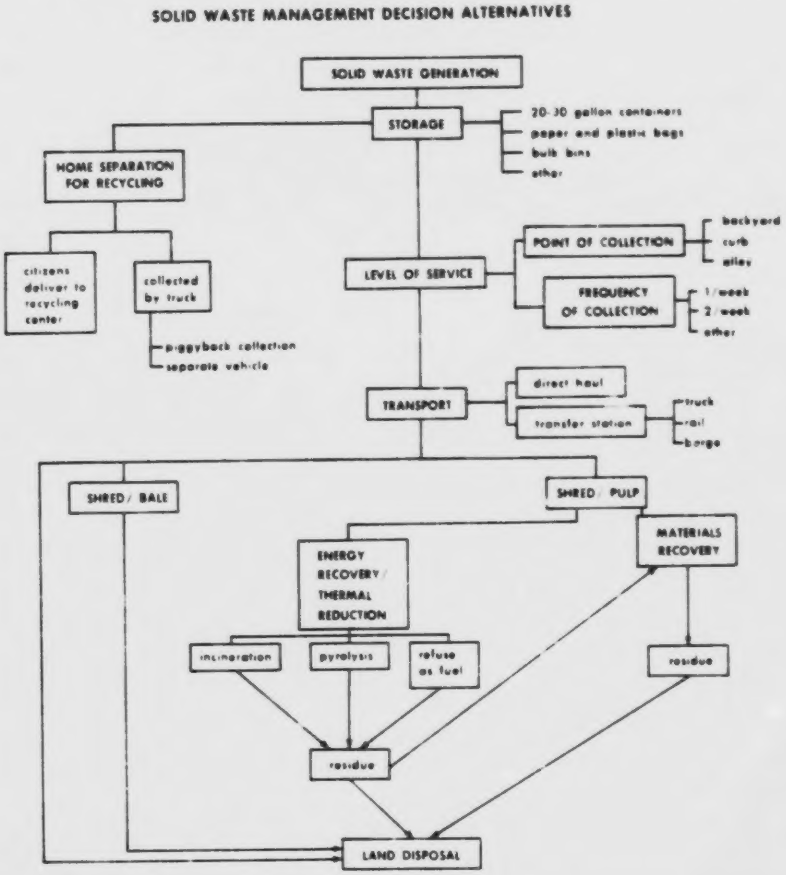
SOLID WASTE MANAGEMENT DECISION ALTERNATIVES
SOLID WASTE GENERATION
STORAGE
20-30 gallon containers
paper and plastic bags
bulk bins
other
HOME SEPARATION FOR RECYCLING
citizens deliver to recycling center
collected by truck
piggyback collection
separate vehicle
LEVEL OF SERVICE
POINT OF COLLECTION
backyard
curb
alley
FREQUENCY OF COLLECTION
1/week
2/week
other
TRANSPORT
direct haul
transfer station
truck
rail
barge
SHRED/BALE
SHRED/PULP
ENERGY RECOVERY/ THERMAL REDUCTION
MATERIALS RECOVERY
incineration
pyrolysis
refuse as fuel
residue
residue
LAND DISPOSAL

FIGURE 1. This flowchart illustrates the decisions which must be made from the point of generation to the ultimate disposal of residential solid waste. These decisions encompass the four major solid waste functions: collection (including storage, level of service, and the separation of materials for recycling), transport, processing (including volume reduction through shredding and/or baling and resource recovery), and ultimate disposal.

In designing a solid waste collection system, one of the first decisions to be made is where the waste will be picked up: the curb or the backyard. This is an important decision because it affects many other collection variables, including choice of storage containers, crew size, and the selection of collection equipment.

Another key decision is frequency of collection. Both point of collection and frequency of collection should be evaluated in terms of their impact on collection costs. Since collection costs generally account for 70 to 85 percent of total solid waste management costs, and labor represents 50 to 75 percent of collection costs, increases in the productivity of collection manpower can dramatically reduce overall costs.

Systems with once-a-week curbside collection help maximize labor productivity and result in significantly lower costs than systems with more frequent collection and/or backyard pickup. The main reason many communities retain twice-a-week backyard service is that the citizens demand this convenience and are willing to pay for it.

The choice of solid waste storage containers must be evaluated in terms of both environmental effects and costs. From the environmental standpoint, some storage containers can present health and safety problems to the collectors as well as to the general public. Therefore, the decision facing a community is, Which storage system is both environmentally sound and the most economical given the collection system characteristics? For example, paper and plastic bags are superior to many other containers from a health and esthetic standpoint and can increase productivity when used in conjunction with curbside collection. However, with backyard collection systems, bags have little effect on productivity.

Another factor to be considered in examining storage alternatives is home separation of various materials for recycling. In a number of communities, newsprint is collected for recycling by either the regular collection truck equipped with a special bin for the paper or a separate truck. The primary factor to consider in implementing a separate collection system is whether the benefits of paper recovery outweigh the costs involved. The economic viability of separate collection depends primarily on the local market price for the paper and the degree of participation by the citizens. If these factors are positive, it may be possible to implement a paper recovery system with no increase and perhaps even a savings in collection operating costs; often no additional capital expenditures are required.

The distance between the disposal site and the center of the city will determine the advisability of including a transfer station in the transport system. In addition to distance traveled to the disposal site, the time required for transport is a key factor, especially in traffic-congested large cities.

The tradeoffs involved in transfer station operations are the capital and operating costs of the transfer station as compared to the costs (mostly labor) of having route collection vehicles travel excessive distances to the disposal site. These tradeoffs can be computed to find the point at which transfer becomes economically advantageous.

The sheer quantities of solid waste to be disposed of daily makes the problem of what to do with the waste, once it has been collected, among the most difficult problems confronting community officials.

A crisis situation can develop very quickly, e.g., in the case of an incinerator or land disposal site forced to shut down because of failure to meet newly passed environmental regulations, or it can build gradually over a period of time if needed new facilities are not properly planned for and put into service.

There are three basic alternatives for disposal, with subalternatives for some of them (Table 1). The three major alternatives are: direct disposal of unprocessed waste in a sanitary landfill; processing of waste followed by land disposal; and processing of waste to recover resources (materials and/or energy) with subsequent disposal of the residues.

Direct haul to a sanitary landfill (with or without transfer and long haul) is usually the cheapest disposal alternative in terms of both operating and capital costs. It may not always be the best from an environmental standpoint because of the danger of water pollution from leachate. This alternative is also wasteful of land and resources.

With the second alternative, processing prior to land disposal, the primary objective of the processing is to reduce the volume of wastes. Such volume reduction has definite advantages since it reduces hauling costs and ultimate disposal cost, both of which are, to some extent, a function of waste volume. However, the capital and operating cost to achieve this volume reduction is significant and must be balanced against the savings achieved. An additional consideration is the environmental benefits which might be derived from the volume reduction process.

The third category of disposal alternatives are those processes which recover energy or materials from mixed solid waste. In terms of economics, there are significant capital and operating costs associated with all these energy and/or materials recovery systems. Revenues from the sale of recovered products will reduce the net costs of recovery, however. Not only do resource recovery systems achieve the goal of resource conservation, but the residuals of the processes require much less space for land disposal than unprocessed wastes.

Affecting all four major functions are basic decisions regarding how the solid waste system will be managed and operated. This includes how the system will be financed, which level of government will administer it, and whether a public agency or private firm will operate the collection, transport, processing, and disposal functions. The criteria most relevant for making these decisions are the institutional factors of political feasibility and legislative constraints.

Financing is needed for operating costs and capital costs. For operating revenues, there are two sources: the city's general tax fund or a direct charge on the users of the system. A direct charge may be a fixed sum or vary according to the level of service rendered. The issue of political feasibility becomes relevant when a change from tax financing to a user charge is being considered. There is often citizen opposition to receiving a bill for a service which was previously provided "for free" (hidden in the property tax).

For capital expenditures, municipalities have basically two alternatives: borrowing and current revenues. The decision of which method will be used is affected by factors such as the financial status of the city, citizen attitudes, legislative constraints on debt limits or

TABLE 1

COMPARATIVE ECONOMICS AND FEASIBILITY OF MAJOR RESOURCE RECOVERY AND DISPOSAL OPTIONS

Alternative	Feasibility	Net operating cost per ton*
Sanitary landfill	Institutional—there may be active citizen opposition to potential locations. Technical—depends on geological characteristics of the land. Economic—decided savings in cost per ton if facility handles over 100 tons per day.	$1.50-$8
Conventional incineration	Technical—feasible. Economic—cannot economically meet new air pollution standards.	$8-$15
Small incinerator	Technical—feasible. Economic—varies with particular case.	$8-$15
Steam generation from waterwall incinerators	Technical—several incinerators are in operation, only 2 are marketing the steam produced. Economic—markets for steam are limited.	$4-$10
Solid waste as fuel in utility or industrial boiler	Institutional—owner/operator must contract with utility for sale of electricity. Technical—combustion in utility boiler as supplement to coal has been demonstrated in St. Louis. Economic—practical feasibility depends on cooperation of local utility or user industry.	$6-$10
Pyrolysis:		
Solid waste converted into combustible gas and oil	Technical—has been demonstrated at 200-ton-per-day pilot plant. Economic—transportability and quality of the fuel produced are primary factors. Ability to store and transport fuel offers broad market application.	$4-$12
Heat recovery to generate steam	Technical—1,000-ton-per-day plant is in shakedown operation in Baltimore. Air pollution problems have been encountered. Economic—markets for steam are limited.	$4-$8
Materials recovery:		
Newsprint, corrugated, and mixed office papers	Technical—separate collection, possibly with baling, is required. Economic—markets are variable; when paper prices are high, recovery can be profitable.	

(Continued)

TABLE 1

COMPARATIVE ECONOMICS AND FEASIBILITY OF MAJOR RESOURCE RECOVERY AND DISPOSAL OPTIONS—*Concluded*

Alternative	Feasibility	Net operating cost per ton*
Mixed paper fibers	Technical—technology has been demonstrated at 150-ton-per-day plant in Franklin, Ohio. Economic—fiber quality from Franklin plant is low, suitable only for construction uses. Quality can be upgraded by further processing.	$7-$13
Glass and aluminum	Technical—technology being developed. Economic—market potential is adequate but system economics uncertain as yet.	

*Includes amortization of capital equipment.

long-term contracts, and the size of the project to be undertaken.

The ownership and operation of residential collection systems range from completely public collection to collection by private contractors in open competition. One common pattern is the collection of residential waste within the city limits by a municipal system under the public works department and collection of adjoining suburban areas by private contractors. In other communities, collection is divided between the public and private sectors with private contractors operating under exclusive franchises with the city. These are just two of the many patterns of ownership and operation of the collection function which exist within the country today. The ownership and operation of processing and disposal functions are also under public and private auspices and combinations of both.

Regardless of whether solid waste management systems are operated by the public or private sector, the local community must establish regulatory control over these activities. A local regulatory program should include: developing and implementing ordinances and regulations; establishing inspection, monitoring, and complaint procedures and programs; initiating enforcement procedures and programs; and developing bid specifications and awarding contracts for services to be provided by private firms. EPA has promulgated "Guidelines for Thermal Processing and Land Disposal of Solid Waste" (40 CFR 1, 240 and 241), and is currently in the process of developing guidelines for the storage and collection of solid waste, source separation for materials recovery, beverage containers, recovery of resources from mixed solid waste, and the procurement of goods that contain recycled materials. These guidelines are mandatory only for Federal facilities; however, they can provide guidance to local officials and should be incorporated in local ordinances where appropriate.

The following pages (Tables 2-13) present a brief overview of major issues and the alternatives available in dealing with them, plus the advantages and disadvantages of each alternative and the conditions which favor one alternative over another. These and related issues are presented in detail in the chapters of this guide.

TABLE 2

POTENTIAL ADVANTAGES AND DISADVANTAGES OF CURBSIDE/ALLEY AND BACKYARD COLLECTION, AND CONDITIONS THAT FAVOR EACH

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Curbside/alley	More efficient Less expensive Requires less labor Facilitates use of paper or plastic bags Reduces collector injuries Requires less fuel	Cans at curb look messy Special arrangements must be made for handicapped and elderly Residents must remember day of collection	High collection costs Unwillingness on part of residents to pay higher taxes or user charge
Backyard	No effort required by residents No mess at curbs	More expensive High labor turnover Increases number of collector injuries Requires more fuel	Quality of service provided more important criterion than economics

TABLE 3

POTENTIAL ADVANTAGES AND DISADVANTAGES OF TYPES OF RESIDENTIAL WASTE STORAGE CONTAINERS, AND CONDITIONS THAT FAVOR THE USE OF EACH

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Paper or plastic bags	Easier to handle—no lids to be removed or replaced Less weight to lift Reduces spillage and blowing litter when loaded in truck One-way container—no cans left at curb Eliminates odors and necessity to clean dirty cans Prevents fly entrance Increases speed and efficiency of collection Reduces contact of collector with waste	Cost per bag Bags can fail if overfilled or if too thin Susceptible to animal attacks Not suitable for bulky, heavy, or sharp objects May be difficult to obtain due to energy crisis	Curbside collection
Metal or plastic cans (20- to 30-gal)	Reasonable size for collector to lift Economical	Must be cleaned regularly when not used with liners	Backyard collection
Bulk containers for mechanized collection	More efficient than manual collection	Residents oppose storage of other people's waste on their property	Alley space available for storage
Drums (55-gal)	None	Lower collection efficiency Excessive weight can result in back injury and muscle strain Difficult to handle Lack of lids allows insects to breed in waste and odors to escape Rust holes at bottom of drum allow rodents to feed on waste	Unacceptable alternative
Stationary storage bins	None	Inefficient—must be emptied manually Lack of proper cover leads to insect and rodent infestation Necessity for hand shoveling of wastes poses health hazard to collectors	Unacceptable alternative

TABLE 4

POTENTIAL ADVANTAGES AND DISADVANTAGES OF DIFFERENT FREQUENCIES OF COLLECTION, AND CONDITIONS THAT FAVOR EACH

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Once per week	Less expensive Requires less fuel	Improperly stored waste can create odor and fly problems	Adequate storage provisions Cold to moderate climate
Twice per week	Reduces litter in urban areas Reduces storage volume requirements	More expensive Requires more fuel	Quality of service provided more important criterion than economics Warm climate
More than twice per week	Reduces litter in urban areas Reduces storage volume requirements	More expensive Requires more fuel	Seriously restricted storage space Dense population

TABLE 5

POTENTIAL ADVANTAGES AND DISADVANTAGES OF SOURCE SEPARATION OF RECYCLABLE MATERIAL FROM SOLID WASTE, AND THE CONDITIONS THAT FAVOR IT

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
All alternatives: separate collection, piggyback collection, recycling centers	Simple to implement Reduces solid waste volume at sanitary landfill If paper prices are high there may be a decrease in collection costs	Requires citizen cooperation Requires market for separated waste materials Results in separation of only a small portion of the total waste stream Scavengers may take material for private gain	Markets exist for the materials recovered Citizen support of resource recovery is high

TABLE 6

POTENTIAL ADVANTAGES AND DISADVANTAGES OF METHODS FOR COLLECTION IN RURAL AREAS, AND THE CONDITIONS THAT FAVOR EACH

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Disposal by residents on their property	No cost to local government	Difficult to monitor and control Can lead to roadside dumping and open dumping Requires extensive educational campaign to ensure proper disposal	Isolated areas
Hauling by residents to landfills	No cost to local government	Distance to landfill may discourage regular trips Can lead to roadside dumping and open burning Generates excessive traffic at landfill Poses hardship for persons without means of transportation	Landfills are easily accessible
Centrally located bulk containers	Operating costs are relatively low Promiscuous dumping is reduced Public acceptability is high Sites can be located near users	Initial capital cost may be high Vandalism may occur at unattended sites Difficult to assess user fee Poses hardship for persons without transportation If implemented near municipalities containers may be used by town residents to avoid paying for collection service	Roads allow passage of collection vehicles
Mailbox system	Collects from largest number of people User fees can be established	Residents must remember collection day Waste may be spilled at roadside prior to pickup Time consuming and costly in isolated areas	Population is fairly concentrated

TABLE 7

POTENTIAL ADVANTAGES AND DISADVANTAGES OF DIRECT HAUL TO DISPOSAL SITES AND USE OF TRANSFER STATIONS, AND THE CONDITIONS THAT FAVOR EACH METHOD

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Direct haul by collection trucks to disposal site	Requires no capital expenditure	Changes in disposal site location require rerouting of all collection trucks Nonproductive time spent in transport increases costs	Close-in disposal sites available Low labor rates Nonurban area
Transfer station	Cuts down on nonproductive collection time In-town location where residents can bring their waste Makes collection operation independent of the actual disposal site Facilitates the addition of resource recovery or volume reduction equipment at the transfer site Permits land reclamation (e.g., filling in strip mines) at location distant from generation point Capital and operating costs of collection vehicles are reduced	Requires extra materials handling step Requires capital expenditures for land, structures, and equipment To achieve savings in existing system, a reduction in the number of crews is needed Difficult to find recipient of waste outside of immediate political jurisdiction There is usually citizen opposition to proposed transfer sites if located near residential areas	High labor costs Distant disposal site Large collection crews Shortage of land for sanitary landfills at reasonable price Urban areas

TABLE 8

POTENTIAL ADVANTAGES AND DISADVANTAGES OF SOLID WASTE PROCESSING AND DISPOSAL METHODS, AND THE CONDITIONS THAT FAVOR EACH

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Sanitary landfilling	Simple, easy to manage Initial investment and operating costs are low Can be put into operation in short period of time May be used to reclaim land Can receive most types of solid waste, eliminating the necessity for separation of wastes	Proper sanitary landfill standards must be observed or the operation may degenerate into an open dump Difficult to locate new sites because of citizen opposition Leachate may create water pollution Production of methane gas can constitute a fire or explosion hazard Obtaining adequate cover material may be difficult	*All solid waste systems must have a landfill for unprocessed waste or for the residues resulting from processing facilities*
Sanitary landfilling of baled solid waste	Extends life of landfill (double that of a fill for unprocessed wastes) Lowers operating costs at the disposal site Reduces hauling costs where distant sites are used	Resource recovery is precluded once bale is formed Leachate may create water pollution	Long hauls needed to reach landfill sites Shortage of landfill sites requires maximum utilization of available land
Sanitary landfilling of shredded solid waste	Extends life of landfill Does not require daily cover under some conditions Waste is more easily placed and compacted Vehicles do not become mired in waste in inclement weather Reduces problems with vectors Does not support combustion or lead to blowing litter Shredding at transfer station or at landfills may be first step in implementing a resource recovery system	Jamming and bridging of the feeding equipment can reduce throughput of the mill High level of component wear, especially of hammers Danger to employees from flying objects, explosions, fires within the mills, and noise Leachate may create water pollution Maintenance and repair costs are high	Cover material is difficult to obtain Shortage of landfill sites requires maximum utilization of available land
Incineration	Extends life of landfill May be more economical than hauling unprocessed waste to distant landfill	Large capital investment High operating cost Large expenditures may be required for air pollution control equipment Conventional incinerators generate large quantities of wastewater which must be treated and disposed of	Land available for sanitary landfilling is at a premium Few if any conditions favor conventional incineration

(Continued)

TABLE 8

POTENTIAL ADVANTAGES AND DISADVANTAGES OF SOLID WASTE PROCESSING AND DISPOSAL METHODS, AND THE CONDITIONS THAT FAVOR EACH—*Concluded*

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Materials recovery systems	Less land required for solid waste disposal High public acceptance Lower disposal costs may result through sale of recovered materials and reduced landfilling requirements	Technology for many operations still new, not fully proven Requires markets for recovered materials High initial investment required for some techniques Materials must meet specifications of purchaser	Markets for sufficient quantities of the reclaimed materials are located nearby Land available for sanitary landfilling is at a premium Heavily populated area to ensure a large steady volume of solid waste to achieve economies of scale
Energy recovery systems	Landfill requirements can be reduced Finding a site for an energy recovery plant may be easier than finding a site for a landfill or conventional incinerator Total pollution is reduced when compared to a system that includes incineration for solid waste disposal and burning fossil fuels for energy May be more economical than environmentally sound conventional incineration or remote sanitary landfilling High public acceptance As cost of fossil fuel rises, economics become more favorable	Requires markets for energy produced Most systems will not accept all types of wastes Specific needs of the energy market may dictate parameters of the system design Complex process requiring sophisticated management Needs relatively long period for planning and construction between approval of funding and full-capacity operation Technology for many operations still new, not fully proven	Heavily populated area to ensure a large steady volume of solid waste to take advantage of economy of scale Availability of a steady customer for generated energy to provide revenue Desire or need for additional low-sulfur fuel source Land available for sanitary landfilling is at a premium

TABLE 9

POTENTIAL ADVANTAGES AND DISADVANTAGES OF DIFFERENT CAPITAL FINANCING METHODS, AND THE CONDITIONS THAT FAVOR EACH

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Borrowing			
General obligation bonds	One of the most flexible and least costly public borrowing methods Requires no technical or economic analysis of particular projects to be funded Small projects may be grouped to obtain capital Least difficult to market	Requires voter approval, and elections may be expensive Must not exceed municipality's debt limit Issuing jurisdiction must have power to levy ad valorem property tax Transaction costs impose a benchmark minimum of $500,000 Capital raised becomes part of general city treasury, thus other city expenditures could draw on amount, unless specifically earmarked for solid waste Since careful project evaluation is not required, decision-makers may be unaware of technological and economic risks Ease of raising capital is a deterrent to change in existing public/private management mix, little incentive for officials to consider use of private system operators	Size of community is small or medium Voter approval likely
Municipal revenue bonds	Projected revenues guarantee payment Can be used by institutions lacking taxing power, such as regional authorities and nonprofit corporations Does not require voter approval Is not constrained by municipality's debt limitations	Effective minimum issue of $1 million, thus only useful for capital-intensive projects Information requirements of the bond circular are extensive Technical and economic analysis of project must be performed by experts outside the municipal government Cost is higher than general obligation bonds Can be used only for specific projects	Capital-intensive projects Regional facilities desired Municipality's debt limit has been reached Initiating institutions lack taxing power
Bank loans	Small-scale capital requirements for short-term funding (5 years or less) Some medium-term funding applicability since notes may be refinanced as they expire Relatively low interest cost because interest paid by municipality is tax-free to bank Source of funds on short notice No external technical or economic analysis required	Low maximum Short term Not useful for capital intensive projects	Capital requirement is small Funds needed on short notice

(*Continued*)

TABLE 9

POTENTIAL ADVANTAGES AND DISADVANTAGES OF DIFFERENT CAPITAL FINANCING METHODS, AND THE CONDITIONS THAT FAVOR EACH—*Concluded*

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Bank loans (*cont.*)	Essentially no minimum Relatively inexpensive Voter approval generally not required No debt ceilings Can be used by institutions lacking taxing power		
Leasing	Useful as interim financing for equipment needed before appropriations or long-term capital arrangements can be made Negotiating agreement is simple and fast Only certification required is assurance of municipality's credit standing Reduces demand on municipal capital outlays since original capital raised by private corporation	Relatively high annual interest rate (9-18 percent) Amount of capital is usually limited Lease terms are generally 5 years or less Some States prohibit municipalities from entering multiyear, noncancellable contracts City will not own asset unless it purchases facility upon completion of lease period	Equipment needed before appropriations available Municipality has good credit rating
Current revenue capital financing	Least complex mechanism available No consultant or legal advice required No need for formal financial documents	No cost in the conventional sense (but higher taxes result) Communities' ability to generate surplus capital is frequently lacking Current taxpayers should not have to pay for a system that will be used far into the future Solid waste projects must compete with other municipal demands	Amount of capital necessary is small
Private financing	Municipality need not borrow capital Provides long-term flexibility for municipality	Municipality must locate acceptable firm and negotiate contract Higher cost of capital reflected in system charges There may be legal constraints which prevent signing of long-term contract Displacement of city employees	Municipality's debt limit has been reached Municipality wishes to avoid administrative details of operating solid waste facility.
Leveraged leasing	Reduces demand on municipal capital funds Interest rate on entire financial package may be lower than general obligation bonds	Legally complex City will not own asset unless it purchases facility upon completion of leasing period	

TABLE 10

POTENTIAL ADVANTAGES AND DISADVANTAGES OF TAXES AND USER CHARGES AS SOURCES OF OPERATING REVENUES, AND THE CONDITIONS THAT FAVOR EACH

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Property tax	Simple to administer—no separate billing and collection system necessary If part of local property tax, it is deductible from Federal and State income taxes	Solid waste management is often a low-priority item in the budget and receives inadequate funds Costs are hidden—less incentive for efficient operation Commercial establishments pay taxes for service they may not receive	Tradition of tax financing for most public services
Sales tax	Simple to administer	Variable monthly income Requires voter approval Income may not be adequate Commercial establishments pay taxes for service they may not receive	Recreation areas with high tourist trade
Municipal utility tax	Simple to administer More equitable than ad valorem taxes Can be instituted without voter approval	Variable monthly income Income may be inadequate	Ceiling on property tax rates Tradition of tax financing for most public services
Special tax levies	Voter approval usually not required	Amount limited by statute	Ceiling on property tax rates Tradition of tax financing for most public services
User charges	Enables localities to balance the cost of providing solid waste services with revenues Citizens are aware of costs of service and can provide impetus for more efficient operations	More complex to administer Can cause problems for users on fixed incomes	Ceiling on property tax rates

TABLE 11

POTENTIAL ADVANTAGES AND DISADVANTAGES OF TYPES OF MULTIJURISDICTIONAL APPROACHES

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Authority	Can finance without voter approval or regard to local debt limit Political influence minimized because board members are private citizens Autonomous from municipal budgetary and administrative constraints Can generate income to make service self-supporting Capital financing is tax exempt	Financing is complex Can become remote from public control Can compete with private industry in some areas, reducing efficiency of both	Debt ceiling prohibits financing by the municipality Voter approval of financing will delay urgent project Political activity has hindered activity in past Autonomy from municipal budgetary and administrative control would mean more efficient delivery of service
Nonprofit public corporations	Tax-exempt status Can finance without voter approval or regard to local debt limit Assets revert to community after bonds are paid	Political influence may be exerted because board members are government officials Difficult to dismantle even if better service can be provided by other sources Financing is not backed by full faith and credit of community	City wishes to shift financing requirements to an organization outside municipal bureaucracy City wishes to avoid administrative details of providing solid waste management services
Multicommunity cooperative	Tax-exempt status is available Does not require State approval	Member communities lose some autonomy Ability to raise capital depends on lead community's debt capacity and financing strength Lead community can be hurt financially unless contracts with other communities are written properly	One city is willing to take lead in securing financing
Special districts	Constituency is a distinct group of residents, not scattered bond holders Local autonomy can be protected by having county officials serve on board	Powers limited by State statute Must rely on special tax levies requiring voter approval Creates an additional unit of government not directly elected by citizens	No other governmental unit can provide service
Governmental agreements	Flexible and enforceable method of cooperation Basic governmental structures are not changed Can be implemented quickly and easily	May be difficult to raise capital since each community must borrow No single corporate body, so all communities must agree on any decision If contracts are not carefully written, misunderstandings may arise	Service or function to be provided is not costly or complex

TABLE 12

POTENTIAL ADVANTAGES AND DISADVANTAGES OF TYPES OF PUBLIC AND PRIVATE OWNERSHIP AND OPERATION OF COLLECTION SERVICES, AND THE CONDITIONS THAT FAVOR EACH

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Public:			
Municipal department	Tax-free Nonprofit Economies of scale City has administrative control Can institute separate collection for recycling Can institute mandatory collection Management and policies are continuous over time, resulting in experienced personnel and permitting long-range planning Records can be kept over a long time	Monopolistic Lack of incentive to maximize efficiency Financing and operations often influenced by political constraints Frequently financed from general tax fund and subject to 1-year budgeting process Solid waste management often low-priority item in budget Labor pressures may result in inefficient labor practices and strikes Restrictive budget policies may affect equipment replacement and maintenance Policies of job-support inflate labor costs	Past history of unsatisfactory contractual operations for public services Public predisposition towards government operation of public services Quality of service provided more important criterion than economics
Private:			
Private firms with contract from governmental unit	Competitive bidding for contract(s) helps keep prices down City retains administrative control Can institute separate collection for recycling Can institute mandatory collection	Danger of collusion in bidding Public agency must regulate contractors	Flexibility is needed to make changes in operations that would result in labor savings and other cost reductions Existence of qualified private contractors Public predisposition towards private sector involvement in public services Newly incorporated communities, or where population growth is outpacing ability of community to provide public services
Private firms in open competition	Competition may reduce costs Self-financing	City has no administrative control Danger of collusion among haulers to reduce competition and keep prices high Cutthroat competition can result in business failures and service interruptions Overlapping routes, waste of fuel Cannot institute citywide separate collection for recycling Difficult to enforce mandatory collection ordinances	Unacceptable alternative

(Continued)

TABLE 12

POTENTIAL ADVANTAGES AND DISADVANTAGES OF TYPES OF PUBLIC AND PRIVATE OWNERSHIP AND OPERATION OF COLLECTION SERVICES, AND THE CONDITIONS THAT FAVOR EACH—*Concluded*

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Private firms with exclusive franchises	Self-financing	City has no administrative control Monopolistic, can lead to high prices Cannot institute separate collection for recycling Difficult to enforce mandatory collection ordinances	Unacceptable alternative
Combination of public and private:			
Municipal system and private firms under contract	Competition helps keep price down Alternative available if either sector cannot deliver service City has administrative control Can institute separate collection for recycling Can institute mandatory collection		Municipality is expanding through annexation or merger with other jurisdictions Changing from separate garbage and trash collection to combined collection
Competition between municipal system and private firms	Competition helps keep prices down	Overlapping routes, waste of fuel Can't institute citywide separate collection for recycling Lack of mandatory collection	Unacceptable alternative

TABLE 13

POTENTIAL ADVANTAGES AND DISADVANTAGES OF PUBLIC AND PRIVATE OWNERSHIP AND OPERATION OF PROCESSING AND DISPOSAL FACILITIES, AND THE CONDITIONS THAT FAVOR EACH TYPE OF OPERATION

Alternative	Potential advantages	Potential disadvantages	Conditions which favor alternative
Public	Tax-free Nonprofit Can obtain low-interest rates and/or government grants for capital-intensive systems	Community may not have expertise to operate sophisticated capital-intensive facility City may lack marketing expertise Restrictive budget policies may affect equipment replacement and maintenance	Public predisposition towards government operation of public services Creation of public jobs desired Government employees are available to operate facility
Private	Local government does not need to raise capital Often easier for private firms to buy land for a processing or disposal site Community does not bear entire risk associated with new technology	Community may have no control of fees if only privately operated facilities are available Operator may base decisions on basis of financial reward rather than community needs Legal constraints may prevent city from signing long-term contract Displacement of city employees Municipality must locate acceptable firm and negotiate contract	Borrowing power of community and/or voter approvals for bond issues needed for capital improvements in disposal facilities are limited or not available Flexibility is needed to make changes in operations that would result in labor savings and other cost reductions Desire of local government to avoid administrative details in operation of disposal facilities Community lacks sufficient technical and management expertise for efficient operation of the type of advanced system it would like to install Territorial flexibility is needed to permit operation across political boundaries, where appropriate regional agencies do not exist Commercial markets are available for recovered products Desire to bypass civil service regulations

conservation, environmental effects decisions collection, transport, processing, disposal criteria cost, institutional factors, resource conservation,

INSTITUTIONAL AND ORGANIZATIONAL APPROACHES

conservation, environmental effects decisions collection, transport, processing, disposal criteria cost, institutional factors, resource conservation,

Public or Private Ownership and Operation of Collection Services

In contrast to many other public services, solid waste collection is often under mixed public and private auspices rather than being exclusively a government service. A key decision in solid waste management is, "Who should collect the waste?"

ALTERNATIVES

Residential collection service is most frequently provided through one of four basic arrangements:

- Public (municipal) collection, usually under a governmental department such as the department of public works. Under this structure, collections are made by city employees with city equipment.
- Private firms with a contract from a governmental unit to collect from residences in a given area. Under this approach the contractor owns the equipment but must meet all performance criteria established by the contract. The contract may or may not be awarded on the basis of competitive bidding.
- Private firms in open competition, with little, if any, city regulation. Under this approach, the private collector makes his own arrangements with the customer for pickup.
- Private firms operating under exclusive franchises by which each is licensed to operate alone in a given area. A franchise may or may not be awarded on the basis of competitive bidding.

In addition, there are numerous variations on these four basic types and various combinations of public and private systems in some cities. An example of such a combination is the situation where a municipally operated system collects a portion of the residences and private collectors under contract to the city collect the remaining stops.

COSTS

One of the key issues that has been debated is whether municipal or private collection results in lower collection costs. It has been argued that municipal systems should cost less since they do not have to earn a profit nor pay taxes, and they pay lower interest rates when they borrow. A private collector, on the other hand, has to earn a profit, and must include taxes and interest on capital in his costs. In addition, there is the expense to the municipality of licensing and monitoring the operation of private collectors.

The most frequently cited reasons for lower private costs are: better management, more efficient use of labor, and revenues from the recycling of reusables. In all cases the desire for profits is seen as a key element in reducing costs. The loss of tax revenues if the public owns and operates the system must also be taken into account in comparing costs.

The question of whether costs are lower under either municipal or private operation should be evaluated by each community.

ADVANTAGES AND DISADVANTAGES

Public (Municipal) Operations

Ownership and operation of the residential collection service by the local government is a common practice. A recent survey by the International City Management Association of cities over 10,000 population indicated that 61 percent of the cities operated a residential collection system. However, only a little over half of these municipal systems collected all of the city's residential solid waste.

The advantages of this alternative include the nonprofit tax-exempt status of public operations which can result in reduced costs or additional service. Municipalities, especially the larger cities that have centralized their purchasing operations, can also reduce costs by buying equipment, gasoline, and other supplies in large quantities.

In addition to potential cost savings, public collection systems have management and policies which are continuous over a long period. This makes it possible to profit from long experience and training, and develop long-range plans. Continuous records may be kept over a long time, and these can be a valuable resource. Also, administrative control of the collection system by a public agency is often necessary for the implementation of collection policies which require systemwide compliance to be effective. Examples of such policies include mandatory collection requirements and the implementation of separate collection of newsprint and other materials for resource recovery.

The disadvantages of public ownership and operation of the collection system include the monopolistic nature of such operations which can result in a lack of stimulus toward efficiency. In establishing labor policies such as crew size and daily work tasks, administrators of public systems may be constrained by labor-union pressures and stated or unstated policies of job support. Labor pressures for higher pay, less work, and greater job security limit the flexibility of many public systems to implement labor-saving techniques. Also, labor strikes causing discontinuities in service are more prevalent in the public sector than in private collection firms.

In the area of financing, the solid waste system may be affected by the low priority it is given in many city budgets. This situation can inhibit innovation, and efficiency may be reduced due to inadequate equipment replacement policies.

Private Firms under Contract

The potential advantage of having private firms perform solid waste collection is that the competition between the various firms should keep costs down. Where contracts are awarded under a competitive bidding system, the community can retain control of collection policies and derive the efficiencies of a competitive, profit-motivated collection system.

The disadvantage of this alternative centers upon the need for active regulation by a public agency. Contracts should be awarded on a bid basis with specifications featuring positive incentives for contractor firms to maintain and improve efficiency. The absence of these controls may result in excessive collection costs.

Private Firms in Open Competition

While competition may keep prices low, a situation with no administrative control over solid waste collection can degenerate into cutthroat competition and severe price cutting, leading to a high rate of business failure and interruptions in service. There is also the danger that the collectors will informally agree to honor each other's territories, thus removing the competitive element and resulting in higher prices. This alternative results in the duplication of resources and inefficient use of fuel.

Private Firms with Exclusive Franchises

The purpose in limiting the number of collectors that operate in a given area is to counteract the negative aspects of excessive competition (business failures, discontinuities in service). Having several collectors operating in the same area also leads to overlapping routes and inefficient use of fuels. The exclusive franchise, on the other hand, creates a monopolistic situation without administrative control by the city. Without such control the collectors holding the franchise may take advantage of the situation by charging excessive rates and lowering service.

OTHER CONSIDERATIONS

If a community's present collection system is unsatisfactory, a change in the institutional organization of the system may be one means of alleviating the problem. The risks in such a change include high initial costs involved in instituting a new organizational structure and the possibility of dramatic social and economic impacts in terms of losses or gains in the number of jobs. Without redesign or reorganization, however, it may be very difficult to change inefficient practices, traditions, and policies, bring in better management, or increase reliability and productivity of the labor force.

The institutional arrangement chosen by a particular community depends on many conditions. Some community situations suggest the preferability of public operation, while others suggest private operation as being more appropriate.

Conditions favoring public ownership and operation would include:

- Public predisposition is toward government operation of public services.
- Quality of service provided is valued more highly than economics.
- Past history of contractual operations for public service is unsatisfactory.

Conditions favoring private ownership and operation would include:

- Public predisposition is toward private-sector involvement in public services.
- Flexibility is needed to make shifts in operation which would produce savings in labor costs and other expenses.
- Local government wants to avoid administrative details in operation of collection system.
- Population growth is outpacing ability of community to provide public services.
- Qualified private collectors are available.

If contracting with a private firm is decided upon, it becomes the job of the local government to administer the bidding process and to monitor and enforce the terms of the contract.

The tools of enforcement consist of the government's ability to withhold payments and ultimately cancel the contract if the firm does not meet minimum performance standards. Besides these drastic measures, positive incentives in the contract for firms to maintain and improve efficiency can have a major effect on their performance. The design of the contract specifications is a crucial factor in assuring that a reputable collection firm is chosen in the bidding process.

The contract specifications must be sufficiently general to attract a reasonable number of bidders, but at the same time restrictive enough to discourage bidding by incompetent or disreputable collection firms. A large number of bidders is important to minimize possible collusion in the bidding process. If there are very few bidders for the contract areas, there is always the potential that competitors will fix their bids so everyone gets a share.

One way to encourage a larger number of bids is to allow sufficient time between awarding of the contract and start of the contract period, so that small firms can obtain the additional resources that may be required should they have the winning bid.

To discourage bidding by disreputable firms, governments frequently require a performance bond from each prospective bidder. Such a bond makes the issuing financial institution liable, up to the amount of the face value of the bond, in the event that the bond-ed contractor fails to abide by the terms of the contract.

Other key issues to be considered in contracting with private firms are: the number of subareas into which a given jurisdiction should be divided; whether or not contracts on all areas should be let simultaneously or staggered over time; the maximum number of subareas any one contractor should be allowed to service; and the length of the contract period.

The greater the number of subareas into which the jurisdiction is divided, the greater the number of collectors the jurisdiction can support, and the greater the number of collectors who must be available for bidding. Care must be taken in dividing the jurisdiction so that each subarea is in fact large enough to support a collector. In addition, it is desirable to stagger the bidding for the various subareas so that the competition for each is more intense.

The number of simultaneous contracts one firm can hold should be restricted to maintain an adequate number of bidders in the area. If one firm holds a large number of contracts, the total number of collection firms the area will support is reduced, and there will be a smaller number of available bidders. However, the limit on the number of contracts one firm can hold should not be too severe, or the competitive spirit will be diminished among the firms holding current contracts. The length of the contract period can also affect the success of the bidding process. A contract period that is too long can reduce the collector's incentive to maintain high quality service, but the contract should be long enough to allow amortization of the collection equipment. EPA recommends a contract period of 3 to 5 years.

Another problem that must be anticipated in contracting with private collectors is the possibility of requests for midterm rate adjustments of a contract. The need to adjust a contract may arise from underbidding by the collector, either deliberately or through inaccurate calculations or unforeseen circumstances such as severe inflation or changes in collection procedures. If such midterm adjustments are relatively easy to obtain, there will be little incentive for accurate bidding and efficient operation over the life of the contract. For this reason, any procedure for permitting midterm adjustments should be rigorous.

To aid cities in designing a contract, EPA and the National Solid Waste Management Association (NSWMA) have developed a model contract. A copy can be obtained from EPA's Office of Solid Waste Management Programs.

Another form of control over private collectors under contract is complaints. A responsive complaint procedure that includes inspection and followup must be an integral part of administering a contract system.

Collection of Commercial Wastes

Collection from commercial establishments (including apartment buildings) is handled primarily by private collectors in open competition. However, the survey conducted by the International City Management Association indicated that approximately 40 percent of the cities surveyed provided some commercial/industrial solid waste collection. In many cases municipal involvement in commercial collection is limited to those stops where residential collection vehicles can be used. Establishments which generate large volumes of waste and require daily collection service are usually served by private haulers.

CONCLUSIONS

In examining whether public or private personnel, equipment, and facilities should be used for solid waste collection, the following issues should be considered: the relative economics and efficiencies of public or private ownership or operation; the ability of the governmental agency to manage a public system and/or contracts; possible legal constraints on the powers of the governmental unit to enter into contracts for services; and the attitudes of the public.

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Public or Private Ownership and Operation of Processing Facilities

In planning for new solid waste processing facilities, whether they are shredders, balers, or resource recovery plants, communities will be considering not only which types of facilities to choose but who should own and operate them.

ALTERNATIVES

The institutional alternatives available range from totally public to totally private ownership and operation with variations in between.

- *Public Ownership and Operation.* A publicly owned and operated facility can be operated either by an established city department or by a public authority which is financially self-supporting and administered separately from other agencies of city government.
- *Public Ownership and Private Operation.* A publicly owned facility could be operated privately either by the system contractor who built the facility for the city, or by an independent service contractor who had nothing to do with plant design or construction.
- *Private Ownership and Public Operation.* This is a rare option but can take place under what financiers call a leveraged lease. Therein the city could lease a plant from investors who help the city finance the facility in exchange for formal ownership of it and the tax advantages such ownership brings (see chapter on Capital Financing).
- *Private Ownership and Private Operation.* Under this approach a system contractor has full responsibility for financing, design, implementation, continued operation, and ownership of the facility. In reality, this full-service contractor is offering the city a service instead of a facility. He will usually charge the city a dump fee for delivered solid waste.

ADVANTAGES AND DISADVANTAGES

While solid waste processing may be carried out by either the public or private sector, it is the responsibility of the government (usually at the local level) to ensure that needed facilities are available, that they are environmentally acceptable, and that future needs are planned for. As processing technologies become more sophisticated, cities must take into consideration such things as technological risk and the degree of management expertise required for a given project, as well as availability and cost of capital. Cities must examine these factors in deciding whether to own and operate their own facilities or have a private firm provide these services. The following discussion presents the advantages and disadvantages to a city of involving private firms in waste processing.

One advantage associated with private ownership and operation is that the local community does not have to finance the system. This is important if the city's borrowing power is limited. The involvement of a private firm also ensures that a community does not bear the entire risk associated with implementing new kinds of technology. A certain degree of risk to the city will always be present, however, since implementing a particular process, through private or public means, usually implies forgoing some other approach. Thus, if a system owned and operated by a private firm fails, the city may not lose any money directly but may find itself in a position of not having adequate disposal facilities.

A potential advantage of private operation lies in the fact that there are private firms which have greater expertise in management of capital-intensive processing facilities than most public agencies. Also, private management tends to be more adaptable to the needs of new systems. In some cities, the operation of such facilities by public employees has been unsatisfactory for a number of reasons, including: union and civil service rules and pay scales that make it difficult to hire and promote only motivated and competent employees, the city's lack of necessary technical and marketing sophistication, and the lack of profit incentives to run an efficient operation. Also, restricted budgetary policies often affect equipment replacement and maintenance.

The primary disadvantage of private ownership and operation is the limited control the city has over the facility. There is the danger that private interests may pursue profits in lieu of service, and that substandard disposal practices or possible plant shutdowns may result.

OTHER CONSIDERATIONS

Conditions favoring public ownership and operation would include:

- An economic study shows this to be more cost-effective.
- The creation of public jobs is desirable.
- Implementation may be easier because government ownership fits in with existing policy.
- Government employees are available for operating the facility.

Conditions favoring private ownership and operation would include:

- Commercial markets are available for recovered products.
- Private financing is preferred and can be obtained more efficiently.
- An economic study shows it to be the most cost-effective.
- Local policy favors private operation.
- A proprietary technology is involved.
- There is a desire to bypass civil service regulations.
- The operation requires people with experience in that particular type of facility.

CONCLUSIONS

It is the responsibility of the public sector to ensure that needed processing facilities are provided and are operated in an environmentally acceptable manner, whether or not they are actually owned and operated by a unit of government. In deciding between private and public operation and ownership of a given facility, a city must evaluate factors such as ability to raise capital, the degree of technological risk involved, the management expertise required, and the expected operating cost.

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Multijurisdictional Approaches

Each year environmental regulations affecting the management of solid waste grow more stringent, while the quantity of waste increases along with capital and operating costs. Many communities are looking toward regional approaches to solid waste management in order to accomplish together what they cannot attain alone. Regionalization offers a number of potential advantages to both large and small municipalities. For example, cooperative procurement of equipment by an intergovernmental entity can frequently lead to lower prices. A vehicle pool can be maintained by such an agency while small municipalities may not be able to afford even one standby vehicle. There may be environmental, financial, and esthetic advantages to having one large, properly run landfill serving an area rather than numerous, often inadequately equipped sites, each serving a small community in the area. The planning and development of resource recovery plants of economical size generally require intergovernmental agreements; regional management of solid waste may also be necessary in order to ensure an adequate supply of waste to the plant and to design the most efficient transportation routes throughout the area.

An intergovernmental entity created for the regional management of solid waste can solicit and accept funding from State, Federal, and other sources; it can allocate costs fairly among local jurisdictions; it can plan comprehensively for transportation and land use as well as waste processing and disposal; it can make a systems approach to resource recovery more feasible; and it can eliminate the need for direct Federal and State controls by being better able to meet standards and laws. The task facing local governments is to determine the conditions under which a multijurisdictional approach is best for them, and which type will best meet their needs.

ALTERNATIVES

Several types of regional organizations that have been created for financing and management of solid waste systems are: (1) public authorities, (2) nonprofit public corporations, (3) multicommunity cooperatives, and (4) special districts. There is considerable variation among existing organizations in each of these categories as a result of differing local and State laws and specific needs and peculiarities of the participants. The differences between various approaches is in the method of formation and the allowable powers. Each type of organization is formed under enabling legislation of the State. The powers of each, such as financing, operating, regulating, and administering, may be generally described as follows.

AUTHORITIES

An authority is a corporate body which usually has a charter, is authorized and approved by a State legislature, and can function outside the regular structure of government to finance, construct, and operate revenue-producing public enterprises. It can be established by municipalities and counties and may have regulatory abilities, usually limited to its own operations, if so stated in its charter.

Most municipalities or groups of municipalities establish an authority to provide a revenue-generating service when confronted with one or more of the following situations:

- The constitutional debt ceiling prohibits financing by the municipality.
- Gaining voter approval for financing will be too time consuming in view of the urgent need for it.
- Political activity related to the service has hampered previous programs.
- Greater autonomy and freedom from municipal budgetary and administrative control will mean more efficient delivery of service.

The authority is well suited for financing and managing solid waste services. It can raise capital dollars from short- and long-term notes and from revenue bonds. It cannot, in most States, raise capital or operating dollars from taxes. The authority normally does not have power to tax and cannot rely on the tax base of a given political jurisdiction unless officials of that jurisdiction allocate funds. Therefore, the operating funds and a portion of the capital funds are raised by levying charges on the users of the authority's service; the charges should generate sufficient income to make the service self-supporting.

Financing through an authority is administratively complex because the authority must be designed and approved by another governmental body or bodies. The ability of the authority to raise capital depends on the debt provisions of its charter, and also on the performance of its management in day-to-day operation and in meeting all the authority's financial obligations. The cost of capital to an authority will depend on what type of debt issue is used plus how well the authority has performed. Capital financing is tax exempt.

Although there are potential advantages to establishment of an authority, there is a danger that it can become remote from government or public control. Separated from the municipal bureaucracy, protected by a board of directors, the authority can become self-serving.

Nonprofit Public Corporations

The nonprofit public corporation is similar in many respects to the authority as a means of financing and managing a solid waste system. The creation of this corporate entity requires approval of articles of incorporation by member jurisdictions and by the secretary of state or other official of the State as designated by law. These corporations are limited in scope and most depend on local action for all regulatory functions. Using this form of corporate body, a city can shift its financing requirements to an organization outside the immediate municipal bureaucracy.

The major reasons for a community to create a nonprofit corporation to perform solid waste services are ease of administrative and legal approval and the presence of a long-term commercial interest in the services rendered.

The nonprofit corporation can be established by one or more cities, counties, or by a group of private individuals. The important feature is that the organization is tax exempt and can issue tax-exempt bonds. To gain tax-exempt status, the corporation must satisfy the following Internal Revenue Service criteria:

- The city council must approve the project and accept the assets after bonds are paid.
- The corporation must agree to give its assets to the city after bonds are paid.
- The city must provide all easements to the corporation at no cost.
- The directors of the corporation must be city or State officials.

- The corporation must provide a public service.

A municipality thus has more control over a nonprofit public corporation than it does over a profitmaking firm.

The ability of the nonprofit corporation to raise capital depends on its ability to secure contracts for its services and its performance of the service, as well as any provisions in its charter which limit the type of debt or the amount of debt. The cost of capital to a nonprofit corporation will depend on the type of debt issued and the performance of the corporation. In theory the cost of capital to the nonprofit corporation should reflect the degree of risk perceived in realizing revenues because it will not have the security of the full faith and credit of a community behind it. Hence there is incentive to make investments that are quite certain to work technically and to ensure that costs of services are covered, at least to the break-even point, by contracts with users.

Many nonprofit corporations provide services through the private sector by contracting with commercial solid waste collection and/or disposal firms on an areawide basis.

Multicommunity Cooperatives

The multicommunity cooperative is a system developed by one community to provide service to itself and several other communities. The purpose is to achieve economies of scale through better utilization of capital and more efficient management.

The approach offers several attractive features. It enables member communities to provide large-scale services not otherwise financially possible. It centralizes waste processing and disposal, and reduces the number of small, inefficient, environmentally unsound systems operating in the area. Urban communities with no landfill area and with limited opportunities for incineration would benefit from a regional arrangement where the options are broader. This approach enables one political jurisdiction to take the lead, while contractually bound supporting communities indicate to the financial interests that the service will be used and sufficient revenues will be generated. The regulatory functions are borne entirely by the individual local governments.

Evaluation of the multicommunity approach as a financing mechanism is really an analysis of the community which will issue the debt in behalf of the other communities. Although each city council must approve the concept and the working agreements, the ability to raise capital will depend on the lead community's debt capacity and financial strength, which may be strained by the extra load. Tax-exempt status is available for financing of multicommunity cooperatives.

The multicommunity approach obviously depends largely on the willingness of independent communities to work together and, in particular, to let one community take a dominant role. The process of organizing the communities for cooperative action is time consuming. Where the problems can be surmounted, however, the multicommunity approach should encourage more efficient, better quality systems.

Special Districts

A "special district" is an agency of government which operates outside the regular structure of government to perform usually a single function and which relies for financial support primarily on special tax levies. Its creation requires the cooperation of the State and the political entities already existing within the region. To implement a successful program, the special-purpose district must continue to be responsive to local needs and to cooperate with local jurisdictions.

In some States special districts can regulate, levy assessments, operate, contract, or do whatever is necessary to perform their single function.

In some instances, special-purpose governments must be used because of State restrictions or because no other governmental unit can be used. The special district has an advantage over the public authority in that the district has a distinct constituency of residents, not merely a group of bondholders living in widely scattered places.

If a special district is used for providing solid waste services, the overall planning function of the general-purpose governments can be protected by having elected county officials with responsibility for solid waste management serve as the governing body of the new unit of government.

Other Techniques

Governmental agreements can be made on a formal or informal basis. A county can, for example, make a formal agreement with one or many cities within its boundaries to perform a certain service for a predetermined fee.

Informal agreements between local governments are frequently made but are not advisable since they can lead to misunderstanding. Any initial agreement should be put down in writing in adequate detail to avoid later disagreement.

Agreements and contracts are without a doubt the most widely used formal method of cooperation among governments in the United States. They constitute a flexible yet predictable and enforceable approach. They can be used to accommodate special program needs without affecting basic structure and organization. Consequently, needed services can be provided and necessary projects undertaken without waiting for major decisions on governmental reorganization, which ultimately may be necessary. The ideal organizational pattern may well be politically unfeasible.

Another relatively simple arrangement is the transfer of function, which occurs when one level of government delegates responsibility for a function to another level or jurisdiction. For example, in Broome County, New York, most of the cities and towns have agreed to transfer the function of solid waste disposal to the county. Similarly, Montgomery County, Pennsylvania, gained responsibility for solid waste management in all parts of the county because an increase in its population caused it to be reclassified under the State's system.

ADVANTAGES AND DISADVANTAGES

Authorities

Advantages:

- Ability to finance without regard to local debt ceiling and without obtaining voter approval.
- Service cannot be hampered by local political activity because board members are usually private citizens.
- Autonomy and freedom from municipal budgetary and administrative control means more efficient delivery of service.
- Can generate sufficient income to make service self-supporting.
- Capital financing is tax exempt.

Disadvantages:

- Financing is administratively complex.
- Can become remote from government or public control, thus may become self-serving.
- Can compete with private industry in some areas of operation, reducing the efficiency of both.

Nonprofit Public Corporations

Advantages:

- Financing is outside government debt limits and can be obtained without voter approval.
- Corporation gives assets to cities after bonds are paid.
- No real estate or Federal taxes, and capital financing is tax exempt.

Disadvantages:

- Political influence may be exerted and flexibility lost because board members are city, county, and State officials.
- Difficult to dismantle even if better service becomes available.
- Does not have full faith and credit of communities behind the financing.

Multicommunity Cooperatives

Advantages:

- Achieves economies of scale because of better utilization of capital or more effective contractual arrangements.
- Enables member communities to provide service not otherwise financially or administratively feasible.
- Encourages more efficient, better quality systems.

Disadvantages:

- Member communities lose some autonomy in locating waste disposal sites, setting charges for use of system, and other decisions.

- Increased interest costs when leading community is less creditworthy than other members.
- Leader community could be hurt financially unless proper contractual arrangements are made with member communities.

Special Districts

Advantages:

- The district has a distinct constituency of residents, not merely a group of bondholders living in scattered places.
- Governments can be protected by having elected county officials serve as governing body of district.

Disadvantages:

- Powers are limited by State statute.
- Must rely on special tax levies requiring voter approval.
- Creates an additional governmental entity removed from the electorate and thus less responsive to citizens than directly elected entities.

Governmental Agreements

Advantages:

- Contracts present a flexible, predictable, and enforceable method of cooperation.
- Basic governmental structures and organizations are not affected.
- Since no reorganization is required, much time can be saved.

Disadvantages:

- It may be difficult to obtain capital financing since each of the communities, rather than a single unit, must borrow money.
- If agreements are not formalized in detail through a contract or other mechanism, misunderstandings may arise later.
- Since there is no single corporate body all participants must reach agreement each time a new issue arises.

OTHER CONSIDERATIONS

Control of a multijurisdictional disposal operation should be such that users have a voice in decisions affecting them, including the location of offload points, the condition of access roads, hours of operation, and restrictions on items received. On the other hand, disposal operations can be run more efficiently if disposal managers have some control over the timing and amounts of solid waste received. Facilities can then be run at efficient levels of input, and waiting lines for offloading vehicles can be minimized.

CONCLUSIONS

Multijurisdictional approaches can be used to hire better management, spread unit costs over a larger population base, thereby taking advantage of economies of scale, and avoid costly duplication of services. Therefore, such approaches are to be encouraged wherever possible.

Operating Revenues

A critical problem confronting many local governments is the generation of operating revenues for solid waste management. In some communities, costs for solid waste management have increased faster than any other municipal budget item. While most of this cost is attributable to increased wages and equipment costs, the increasing volume of waste collected and the need to meet more stringent environmental standards in disposal operations have also been substantial contributing factors. It is estimated that nationally about 80 percent of costs are for collection, 20 percent for disposal.

ALTERNATIVES

Traditionally, municipally operated solid waste systems have been funded from tax revenues. With increasing pressure on municipal budgets, there has been a trend toward raising new or increased revenues through "user" or "service" charges. In the survey conducted by the International City Management Association of cities over 10,000 population, of the 631 cities responding, 41 percent had a user charge for solid waste collection while 46 percent allocated operating revenues from the general fund. These percentages were about the same for communities who operated their own collection service and those who contracted it out to private haulers.

Although many communities have instituted a service charge as the primary method of funding their solid waste management system, it does not always cover total system costs. The ICMA survey reported only 39 percent of the cities with service charges said that the charges covered total collection costs. Thus one can assume that supplemental funding from general revenue sources was necessary in the other 61 percent of communities with user charges.

Communities must know their operating costs and the level of service desired before they can make a rational decision on the best means of funding. This information is also necessary to help justify changes in taxes or user charges to the public.

In the absence of a good accounting mechanism, costs of solid waste services tend to be underestimated. Most of the underestimation is in the area of overhead costs for items such as inspection and enforcement programs, information and education programs, legal and accounting services, and payroll preparation. Often these items are part of the overall city budget and are not apportioned to solid waste management.

In addition, wastes of public or nonprofit institutions, such as schools, churches, hospitals, fire stations, municipal buildings, and county homes, are often collected on a gratis basis with no charge or accounting record. In some communities fees charged to commercial establishments are the same as residential charges, although a commercial source usually generates much more waste than a private residence.

A second important consideration for city officials is the level of service desired. Frequently, municipalities have directed all their efforts toward increasing the tons of refuse collected per man-hour in an attempt to hold down costs. Switching to curbside service, bagged trash, and once-a-week collection can lower costs substantially. But sanitation, appearance, convenience, and public satisfaction may also be affected. Many communities faced with the need for increased operating revenues have chosen to lower service as an alternative to raising additional revenue or converting from general revenue funding to user charges.

Advantages and Disadvantages

Tax Financing

Traditionally, most municipalities funded their solid waste system from the general fund whose primary source was the property tax. Pressed for more operating revenues for solid waste services, many communities have sought other sources of revenue such as the sales tax, a municipal utility tax, or some type of special assessment.

Property Tax. Many communities have successfully utilized a portion of the property tax to support the solid waste management system. This tax has the advantage of being easy to administer since no separate billing or collection system is needed, and payment is virtually guaranteed. Also, many citizens prefer this method of financing since the tax is deductible on Federal and State income tax returns. The primary disadvantage is that solid waste is often considered a low-priority item and must compete with other municipal needs for funding. Second, since solid waste operating costs often are not broken out from other costs, there is less incentive for efficient operation of the system. If cost savings are instituted, the savings usually accrue to the general fund rather than the solid waste system.

Sales Tax. Another possible source of funding for solid waste operations is the sales tax. This option appears particularly attractive in recreational areas with a high tourist trade. The potential disadvantages are a variable monthly income, an inadequate amount of income, and the voter approval that usually must be obtained before implementation.

Municipal Utility Tax. A third method of tax financing for a solid waste system is a municipal utility tax. The tax may be levied on some or all of the utilities in a community whether municipally or privately owned. Utilities commonly subjected to a municipal tax are the telephone, electric, gas, water, and cable TV franchises. Use of this tax eliminates billing problems, and it is more equitable than ad valorem taxes. Usually a municipal utility tax can be set by ordinance without referendum. The disadvantages may be that the amount of income is too limited, the income is variable, and commercial establishments who must contract with private haulers still may pay the tax, for a service they do not receive.

Special Tax Levies. Some State statutes give communities or counties authority to levy a special tax other than those already mentioned. Usually, the amount is limited by statute and is based on the assessed valuation of property; a referendum of the citizens is usually not required. It is often the case, however, that many special tax levy statutes have already been instituted to cover nonbudgeted items such as hospitals, parks, playgrounds, museums, etc., and the solid waste system would have to compete with these projects for funds.

User Charges

Funding solid waste management services through user or service charges is an equitable method if properly administered. It allows a community the opportunity to establish fees on the basis of actual costs of collection and disposal. Although many communities charge a uniform rate, others base their charges on the amount and kind of service rendered.

A straight user charge allocates an equal share of the costs to all users within a service-level group. A user receiving backyard collection may pay more than a user receiving curbside service, but all backyard users are charged the same, regardless of the amount of waste they generate. This type of user charge can be collected by adding a separate solid waste charge to a periodic utility billing or the yearly property tax billing, or through a separate billing system. To avoid added overhead cost and to facilitate collection of bills, it is usually preferable to attach the charge to an already existent billing system. This type of user charge is the most efficient and least costly to administer.

A progressive user charge represents an attempt to correlate costs and service by charging the resident according to the amount of waste he generates. The assessment can be calculated in two ways: (1) a charge for each container collected, or (2) a minimum charge that would cover collection of a certain number of containers plus an extra charge for each additional container.

The first method of assessing progressive charges is well illustrated by the system which requires that plastic bags sold by the collection agency be used, with the charge per bag including both collection and disposal costs, as well as the cost of the bag. On the whole, this approach does not achieve the objective of relating charges to costs, since the increase in collection costs per additional container is not a linear one. The cost of loading the second or third bag does not equal the cost of driving, stopping, and loading the first bag. Under this system, the high-volume user subsidizes the low-volume user.

The second method of assessing progressive charges is more equitable than the first, but it is more difficult to administer. It requires a more complex accounting system to keep track of customers' use of extra containers. A serious problem is controlling the system so that customers get billed for only the number of containers they are using and collectors know how many containers are supposed to be collected from each customer. These administrative difficulties can be alleviated by use of specially marked containers. The distribution of the containers provides a record of how many containers a customer uses, and collection of only specially marked containers guarantees that no extra waste is collected.

Several recent studies indicate that where user charges are instituted or increased, the volume of waste collected decreases. This is because residents charged on a volume or container basis have a tendency to overfill their containers or engage in illegal dumping to minimize their solid waste charge. This can result in loose litter, higher street cleaning costs, and public dissatisfaction.

In actual practice, user charges seldom cover the total cost of operating a municipal solid waste system. Often, the citizens have become accustomed to a nominal service charge and city officials feel the public would raise strong objections to a service charge that actually reflects total operating costs. Obviously, a solid waste system which is self-supporting is highly desirable because money for replacement of equipment, repairs, etc., will be available and an annual fight for additional revenue will not be necessary.

The primary advantages of the user fee are: localities can balance the cost of providing the solid waste service with revenues, and citizen awareness of the cost can provide an impetus for more efficient operation. Primary problems with user charges are billing, difficulties in administration, and the fact that if they are truly reflective of costs, they may be too high for low-income or fixed-income persons.

Disposal Site Fees. The ideal solid waste management system would offer free use of landfill sites. The advantage of free disposal is that it encourages use, whereas charging discourages use. Many communities have compromised by not charging automobiles and pickup trucks while charging commercial haulers, large trucks, and industrial users.

In setting fees the total landfill costs should be taken into consideration. Generally fees should be scaled according to the amount of waste dumped. Accurate determination of the waste load carried by each vehicle entering the disposal area can be a difficult problem. The use of scales is the most equitable method of load determination and should be instituted where possible. Estimating the weight or volume is inadequate, particularly since compaction can vary from 400 to 1,000 pounds per cubic yard. Often fees also depend on the type of refuse received; for example fees are charged for stumps, brush, tires, and building and demolition refuse because these materials are more difficult to compact and cover.

CONCLUSIONS

Regardless of the financing system selected, three things are essential to achieving maximum benefits from it. First, accurate cost accounting is needed to establish and maintain a cost-effective operation. Second, the funds collected for financing the system should be set aside in a dedicated, or earmarked, fund so that they are available as needed for capital replacement and operating expenses. Third, the revenues received should be reflective of the cost of the service provided. Otherwise, not only may the amount of operating revenue be insufficient for the service expected, but awareness of the cost of service among the users is not fostered.

Because of the many factors impacting on solid waste management costs, none of the financing methods described above can be precisely equitable nor would some communities desire them to be. In many cases, one sector of the population subsidizes service to another sector by paying a price higher than the service actually costs.

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Capital Financing

Estimates of cumulative capital expenditures over the next 10 years for solid waste management range from $1.0 to $7.5 billion. These sums will be spent to construct new solid waste facilities and maintain and upgrade existing ones. This immense expenditure is, in part, the result of the need to conform to new Federal and State regulations, the development of more capital-intensive systems, and public demands about the environment. Financing these expenditures has become an increasingly complex and demanding task for municipalities.

Municipalities commonly draw from two basic sources to obtain capital for facilities and equipment: borrowed funds and current revenues. A third alternative is to contract with private firms for the service and shift the capital-raising burden onto them. The decision facing the local government manager is which of these alternatives is the best for his situation—the local conditions and needs. The decision will be controlled by such factors as the financial status of the city, voter attitude, legal constraints on debt limits or long-term contracts, and the magnitude of the project to be undertaken.

ALTERNATIVES

The basic sources of capital considered here are these:

1. Borrowing:
   - General obligation bonds
   - Municipal revenue bonds
   - Bank loans
   - Leasing
2. Current revenue capital financing
3. Private financing:
   - Industrial revenue and pollution control revenue bonds
   - Leveraged leasing

Borrowing

General Obligation Bonds. Among all public borrowing mechanisms available, general obligation (GO) bonds are, in general, the most flexible and least costly alternative. The issuing municipality guarantees a GO bond with its full faith and credit based on its ability to levy on all taxable real property such ad valorem taxes as may be necessary to pay the principal and interest on the bonds.

A GO bond issuance requires no technical or economic analysis of particular projects to be funded. Small projects may be grouped to obtain capital, making GO bonds an ideal funding mechanism for solid waste facilities in small and medium-sized communities.

The transaction costs attendant upon the issuance of GO bonds impose a benchmark minimum of $500,000 on the debt issuance. Any amount below this level prohibitively increases the "effective interest rate."

If total capital requirements of a small or medium-sized community are less than $500,000, it must adopt an alternative financing mechanism, such as borrowing from a bank, leasing equipment and facilities, or contracting for the service from the private sector.

Municipal Revenue Bonds. A mechanism that is often used to circumvent the constraints associated with GO bond issuance is the municipal revenue bond. A revenue bond is issued to finance a single project with revenue-producing services.

Revenue bonds do not have the full faith and credit clause. Rather, they pledge the net revenue generated by the project to guarantee payment. The increased risk associated with revenue bonds yields a correspondingly higher interest rate. The coupon rates on revenue bonds depend strictly on the revenue-generating capacity of the project being financed. Revenue bonds require extensive bond circulars describing the economics of the project.

Bank Loans. A municipal bank loan ought not to be considered an alternative to long-term bond financing. However, relatively small-scale capital requirements may be met in the short run (5 years or less) at a low cost by securing a bank loan.

The most typical use of bank loans in the solid waste field has been to supply short-term funding for rolling stock. Since interest on a loan to a municipality is tax free to the bank, the corresponding interest will compare favorably with the coupon on a GO bond.

Municipalities often use bank loans to stabilize cash flow, and occasionally large cities use bank notes in anticipation of a bond issue. The notes, often substantial if arranged with a large bank, are refinanced as they expire. A medium-term source of funding is thus provided.

Leasing. In lease agreements, the leasing company (the lessor) purchases and holds title to the asset and the lessee pays rent for the use of it during the lease term, usually not more than 5 years for equipment. Longer leases are often made on land. Lease agreements in the solid waste area have usually been arranged by local equipment representatives, who place the financing with either a bank or leasing company. Currently, interest rates on lease agreements are averaging between 9 and 18 percent of the capital cost. Often, stipulations will be included in the contract agreement which allow the city to purchase the equipment at "fair market value" at the end of the lease.

The use of leasing by private solid waste companies is quite prevalent. Small private collection companies that are trying to expand their business may find themselves in a cash flow bind and use this type of financing extensively. Leasing is not so unprofitable for them because the cost of leasing can be written off as a business expense for tax purposes.

Current Revenue Capital Financing

The most common method for obtaining capital equipment for use in a solid waste system has been to buy it as needed. The principal advantage is simplicity, with no institutional, informational, analytical, or legal arrangements required. This method, however, is dependent on the ability of the community to generate surplus capital.

In the solid waste area, current revenue financing has been used mainly for collection vehicles and selected landfill disposal systems. Municipalities that dispose of solid waste using landfills are usually able to maintain the system with current revenues. Equipment replacement is not likely to be a major expense and can be handled periodically. Land can be leased or purchased as an investment. On the other hand, municipalities requiring either extensive upgrading of their systems in the short run or a capital-intensive solution to solid waste problems will have to raise capital by borrowing or by contracting with a private firm.

Private Financing

A third alternative for a community is to contract with a private firm for solid waste management services. The private firm will then raise the capital, purchase the equipment, and operate the system. This approach relieves the municipality entirely of having to devote capital funds to solid waste management and presumably provides the most long-term flexibility.

Industrial Revenue and Pollution Control Revenue Bonds. Industrial revenue bonds (IRBs) and pollution control revenue bonds (PCRBs) are issued by a municipality for or on behalf of a private enterprise. The municipality technically owns the facility and equipment, which it leases to the private firm. The lease payments are specified to meet the scheduled payments of debt and interest on the bond. The municipality thus acts as a vehicle through which a corporation may obtain low-cost financing. If payment arrangements between the corporation and the municipality are structured as an installment sale, the corporation may claim ownership for tax purposes. This gives the corporation a tax benefit in the form of accelerated depreciation or the investment tax credit, which should be reflected in lower service fees charged to the municipality.

The major distinctions between the two types of bonds are (1) the IRBs are limited to $5 million in the amount of capital that they can be used to raise while PCRBs have no such limit, and (2) capital raised through IRBs must be for industrial development while PCRBs must finance pollution control equipment.

In the solid waste field, PCRBs have seldom been used. There are administrative complexities, and broadly defined tax guidelines frequently require IRS rulings which may delay financing by 6 months. Solid waste disposal and resource recovery facilities generally qualify as pollution control projects under section 103c of the IRS regulations, but at this time it is not clear whether entire systems of certain types will qualify. This ambiguity may inhibit the broadest application of PCRBs to finance resource recovery systems.

Another major stumbling block for PCRBs concerns a community's ability to sign long-term contracts with corporations, guaranteeing a minimum supply of solid waste. While the security of these issues requires long-term agreements, many States prohibit communities from entering into long-term service contracts.

Leveraged Leasing. Leveraged leasing is technically not a financial instrument. Rather it is a financial package that combines several financial options. The concept is based upon the benefits (lower long-term capital and interest costs) that accrue to a city if a financial intermediary, a corporation or individual, is interposed between a long-term source of capital and the municipality.

Leveraged leasing, using tax-exempt funds as a debt source, is a new concept that has been applied only twice in the public sector. Its future, however, is promising and it has stirred a great deal of interest in the public financing investment community.

Leveraged leasing is a most complex mechanism to initiate. It involves two major participants, a financial intermediary (lessor) and a city (lessee) (Figure 2). It differs

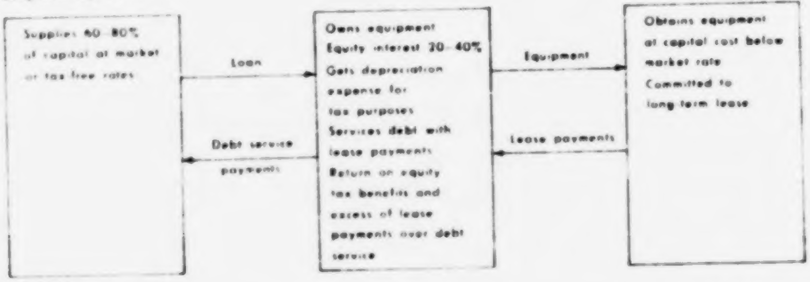
Long term capital source
Supplies 60-80% of capital at market or tax free rates
Loan
Debt service payments
Financial intermediary
Owns equipment
Equity interest 20-40%
Gets depreciation expense for tax purposes
Services debt with lease payments
Return on equity tax benefits and excess of lease payments over debt service
Equipment
Lease payments
Operating company
Obtains equipment at capital cost below market rate
Committed to long term lease

FIGURE 2. A typical leveraged leasing structure uses a financial intermediary to transfer the capital from the capital source. The intermediary leases the equipment bought with the capital to the operating company and uses the lease payments to service the debt to the capital source. Source: RESOURCE PLANNING ASSOCIATES, INC. Financing methods for solid waste facilities. U.S. Environmental Protection Agency, 1974. 376 p. (Distributed by National Technical Information Service, Springfield, Va., as PB 234 612.)

from traditional leasing in that both the lessor and the city provide capital funds to purchase the asset. Usually, the lessor puts up 20 to 30 percent of the cost of the asset, and the city finances the remaining portion through a typical borrowing method.

The financial intermediary acquires the tax advantages of ownership, and therefore can pass on to the city a very low interest rate (lower than GO bond interest rate) on his share of the cost of the asset. The intermediary is able to provide funds to a municipality at a very low interest rate because he is the owner of the entire facility from a tax standpoint and he can depreciate the investment and, in addition, claim a 7-percent investment tax credit if the facility is run by a private corporation. Essentially, the depreciation and tax credit act to shelter the financial intermediary's other income, which allows him to receive an adequate after-tax return on his initial investment in the asset.

The characteristics of each mechanism for financing solid waste systems should be examined so that the means best suited to the particular community will be selected (Table 14).

ADVANTAGES AND CONSTRAINTS

General Obligation Bonds

Advantages:

- One of the most flexible and least costly public borrowing methods
- Requires no technical or economic analysis of particular projects to be funded
- Small projects may be grouped to obtain capital
- Ideal mechanism for small and medium-sized communities
- Least difficult to market

Constraints:

- Requires voter approval, and elections may be expensive
- Must not exceed municipality's debt limit
- Issuing jurisdiction must have power to levy ad valorem property taxes
- Transaction costs impose a benchmark minimum of $500,000 on amount of debt issuance
- Capital raised becomes part of general city treasury, thus other city expenditures could draw on amount, unless specifically earmarked for solid waste
- Since careful project evaluation is not required, decision-makers may be unaware of technological and economic risks
- Ease of raising capital is a deterrent to change in existing public/private management mix; little incentive for officials to consider use of private system operators

Municipal Revenue Bonds

Advantages:

- Project revenues guarantee payment
- Can be used by institutions lacking taxing power, such as regional authorities and nonprofit corporations
- Relatively low interest cost because interest on debt is tax exempt
- Does not require voter approval
- Is not constrained by municipality's debt limitations

Constraints:

- Effective minimum issue is $1 million, thus only useful for capital-intensive projects
- Information requirements of the bond circular are extensive, which may cause delays in raising capital
- Technical and economic analysis of project must be performed by experts outside the municipal government
- Cost is higher than for GO bonds
- Can be used only for specific projects

Bank Loans

Advantages:

- Small-scale capital requirements for short-term funding (5 years or less)
- Relatively low interest cost because interest paid by municipality is tax free to bank
- Some medium-term funding applicability since notes may be refinanced as they expire
- Source of funds on short notice

TABLE 14

CHARACTERISTICS OF CAPITAL FINANCING METHODS AVAILABLE FOR SOLID WASTE MANAGEMENT FACILITIES *

	Types of financing						
Parameter	General obligation bonds	Municipal revenue bonds	Municipal bank loans	Leasing	Current revenue capital financing	Private financing	Leveraged leasing
Complexity of application	No project information required No project analysis required Short lead time	Most complex Bond circular must contain detailed economic and technical information that has been certified by outside consultants Requires more time to arrange	Less complex than bonds, particularly if community has bank line of credit Very short lead time No need for external advice or certification	Relatively simple Minimal analysis required Very short lead time	Least complex of municipal finance alternatives	Problems may include locating acceptable firm, negotiating contract and proposed facilities site, public job reductions, other organizational or management issues Technical and economic analysis performed by private firm	Legally complex New to public finance May require IRS ruling in beginning, therefore requires 6-month lead time
Ability to raise capital	Minimum $500,000 due to fixed transaction costs but can combine several smaller unrelated projects Function of community credit, not a function of particular project	Minimum $1,000,000 due to heavy fixed transaction administrative costs In pure form, not suited for technologically risky projects Maximum is function of projected project revenues	Absence of heavy fixed transaction costs makes it useful for smaller dollar needs Maximum limited by lending capacity of bank Better for short- and medium-term loans than bond	Good for small short-term (5-year) loans Applicable to specific pieces of equipment, especially rolling stock	Current revenue often not available in amounts necessary for major capital expenditures	Depends on credit rating of firm and soundness of project Firms may be limited to smaller amounts of capital than municipality with general obligation bond	Raises 20 to 50 percent of the capital required In pure form, not suited for technologically risky projects Good potential
Cost of capital	Lowest interest rates for long-term capital Interest cost 2-3 percent less than corporate bonds Indirect costs include bond counsel and possibly financial consultant, but costs are relatively low	Somewhat higher than general obligation bond Is directly related to the probability of maintaining adequate revenue Municipality can minimize cost of capital by giving revenue bond the risk attributes of a general obligation bond Indirect costs higher than for general obligation issue	Similar to general obligation bond, in terms of risk and security but affected by loan size and term	High effective annual interest (9-19 percent) Same rate for private, public lessees		Higher for private firm than for municipality Could be lowered through mechanisms like industrial revenue bond or leveraged leasing	If city provides the remaining 50 to 80 percent capital required for the project, the cost of the money is lower than with general obligation bond financing Indirect costs absorbed by lessor
Constraints on use	Voter approval often required Legal debt ceiling may exist Can only be used by jurisdictions with taxing powers	Can be used only for specific projects Good only for relatively large amounts of long-term capital Must be managed by district authority or agency Requires stable, long-term source of revenue	Shorter loan terms than bonds Smaller dollar amounts than bonds	Short term Small dollar amounts State-imposed restrictions on municipalities about signing multi-year noncancellable leases	No legal constraints Economic constraint of amount of available capital	Legal constraint against communities signing long-term noncancellable contracts Insufficient profit potential to compensate firm for risk Administrative legal complexities of potential mechanisms (industrial revenue bonds and leveraged leasing) Mechanisms available do not benefit marginal firms	State restrictions on city's signing multi-year contracts Public decision-makers unfamiliar with concept

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* Resource Planning Associates, Inc. Financing methods for solid waste facilities. U.S. Environmental Protection Agency. 1974. 376 p. (Distributed by National Technical Information Service, Springfield, Virginia, as PB 234 612.)

- No external technical or economic analysis required
- Essentially no minimum
- Relatively inexpensive
- Voter approval generally not required
- No debt ceilings
- Can be used by institutions lacking taxing power

Constraints:

- Low maximum
- Short term
- Not useful for capital-intensive projects

Leasing

Advantages:

- Useful as interim financing for equipment needed before appropriations or long-term capital arrangements can be made
- Reduces demand on municipal capital outlays since original capital is raised by private corporation
- Negotiating agreement is simple and fast
- Only certification required is assurance of municipality's credit standing

Constraints:

- Relatively high annual interest rate (9-18 percent)
- Amount of capital is usually limited
- Lease terms are generally 5 years
- Some States prohibit municipalities from entering multiyear, noncancellable contracts
- City will not own asset unless it purchases facility upon completion of leasing period

Current Revenue Capital Financing

Advantages:

- Least complex mechanism available
- No need for formal financial documents
- No consultant or legal advice required

Constraints:

- No cost in the conventional sense, but higher taxes result
- Communities frequently lack ability to generate surplus capital
- Current taxpayers have to pay for the entire capital cost of a system that will be used far into the future
- Solid waste projects must compete with other municipal demands

Private Financing

Advantages:

- Municipality need not borrow capital
- Provides long-term flexibility for municipality

Constraints:

- Municipality must locate acceptable firm and negotiate contract
- Higher cost of capital reflected in system charges
- There may be legal constraints preventing signing of long-term contract
- There may be displacement of city employees

Leveraged Leasing

Advantages:

- Reduces demand on municipal capital funds
- Interest rate on entire financial package may be lower than GO bond rates

Constraints:

- Legally complex
- City will not own asset unless it purchases facility upon completion of lease period

COMPARATIVE COSTS

When comparing costs of different financial mechanisms, it is important that one not fall into the trap of just reviewing coupon (interest) rates. Coupon rates understate the true costs a city must pay on the capital it borrows. Rather, the municipality should compare the effective interest cost and the debt service rate on the funds it finances. A comparison of costs of raising $10 million through GO bonds, municipal revenue bonds, and revenue bonds with leveraged leases shows how the effective debt service rate differs from the coupon rate and is the significant variable in assessing capital costs (Table 15).

CONCLUSIONS

Because of its simplicity, current revenue financing is the means most commonly used by municipalities to finance collection vehicles and landfill disposal systems. This method, however, is dependent on the ability of the community to generate surplus capital. Thus it is frequently inadequate for capital-intensive projects.

For a project requiring capital in excess of $500,000, a GO bond is probably the quickest and easiest mechanism, provided it has voter support and does not exceed the legal debt limit.

For projects requiring capital in excess of $1 million, the municipal revenue bond may be a desirable source of financing. Although it is a complex approach and may take a great deal of time to arrange, it forces the community to plan carefully, to design a low-risk project, and to conduct a thorough economic analysis in order to assure the necessary revenue-generating capability.

Finally, leveraged leasing should be considered as a source of long-term asset financing. Its disadvantages—newness and complexity of application—seem to be more than offset by the potential cost savings to the municipality.

TABLE 15

EXAMPLE OF COSTS TO FINANCE $10 MILLION THROUGH GENERAL OBLIGATION BOND, MUNICIPAL REVENUE BOND, AND REVENUE BOND AND LEVERAGED LEASING[*]

(in thousands)

Item	General obligation bond (5.7%)	Municipal revenue bond (6.25%)	Revenue bond/ leveraged leasing[†] (4.88%)
Front-end costs			
Rating agency fees	$3	$5	$5
Commission to underwriter	150	250	170
Counsel to underwriter	5	7	7
Counsel to city	10	10	11
Bond counsel	18	40	30
Accountants' fees	8	8	8
Initial trustee fees	6	6	6
Printing and engraving	30	40	35
Third party	—	60	60
Debt service reserve	—	817	572
Election costs	[‡]	—	—
Total	$ 230	$1,238	$ 904
Net proceeds to city	$9,770	$8,762	$9,096
Yearly cost to city [§]	$ 848	$ 883	$ 788
Effective debt service rate [¶]	8.7%	10%	8.6%

[*] Costs for industrial revenue and pollution control revenue bonds are not detailed, since all costs are passed through to the involved corporation. The assumed interest rate for each debt instrument was arbitrary. The actual rate will vary according to the credit-worthiness of a project (or city) and the current capital market conditions.

[†] $7 million by revenue bond, $3 million by lessor. The interest rate is the weighted average cost of capital for the financial package.

[‡] Election costs are unknown.

[§] This is the dollar amount the city would have to pay to retire and pay the interest on the debt. It was assumed that a city made steady payments for the life of the financing to retire the debt. The payments would be made semi annually for 30 years.

[¶] The effective debt service rate is the yearly percentage cost to the city. This is calculated by dividing the yearly cost (interest plus debt retirement) by the net proceeds a city receives.

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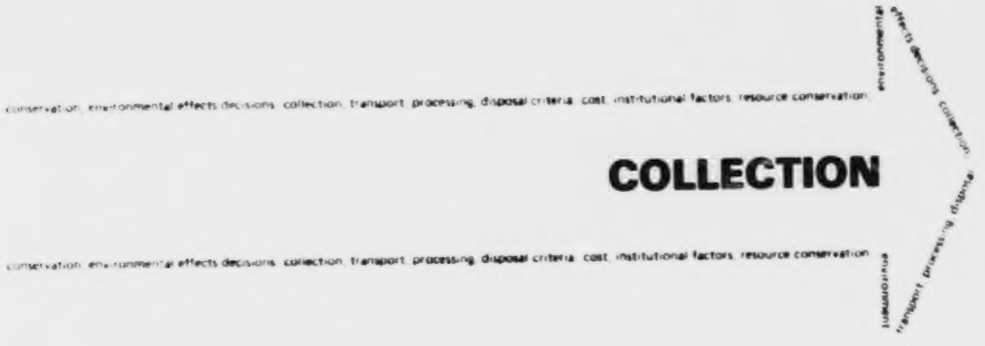
COLLECTION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Point of Collection

Probably the aspect of level of collection service most apparent to the average resident is the point of collection, that is, where the waste is picked up. The decision on this issue affects other aspects of the collection system design such as crew size and storage and is ultimately a controlling factor in the cost of providing the collection service.

ALTERNATIVES

The main issue is who should be the one to carry the refuse from the house to the curb. There are two basic options:

1. Curbside alley collection, which requires the resident to place the solid waste at the curb or alley for collection and to retrieve any empty storage containers.
2. Backyard collection, which usually takes one of four forms:
   - Tote barrel—the collectors walk to the storage containers and empty them into an intermediate container, leaving the storage containers in place.
   - Set out—the collectors carry the refuse in the storage containers to the curb for collection, and the resident retrieves the containers.
   - Set out and set back—the collectors carry the refuse containers to the curb for collection and return them to their storage place.
   - Satellite vehicle system — small-capacity vehicles are used to traverse long distances between the refuse containers and the larger vehicle (e.g., street to backdoor via driveway).

Approximately 60 percent of the collection systems in the United States are curbside and alley; 40 percent are backyard. Recent trends, as evidenced in St. Petersburg and Tampa, Florida; Atlanta, Georgia; Fort Worth, Texas; and Akron, Ohio, are away from backyard and toward curbside. Some communities provide a choice of curb or backyard service and charge a different rate for each.

COSTS

Time spent walking back and forth from curb to backyard is costly, and cost factors have brought pressures for greater efficiency in solid waste collection. Curbside alley collection yields the highest productivity. A savings of 50 to 55 percent may be achieved by using curbside alley rather than backyard collection (Table 16).

OTHER CONSIDERATIONS

Fuel Consumption

Fuel consumption for residential packer trucks is as much a function of time (hours of usage) as miles driven. For many hours each day, the trucks idle their engines on the route while the collectors are handling wastes (particularly in backyard service); also, the hydraulic compaction mechanism consumes substantial amounts of fuel. Indeed, figures for truck usage in curbside systems show 42.6 percent of the time is spent idling on route, 20.7 percent in on-route driving, 30.3 percent in off-route transport and dumping, and 6.4 percent in compaction. For backyard systems idling time is even more (61 percent), while off-route transport and dumping (21 percent), on-route driving (13 percent), and compaction (5 percent) times are less.

Since trucks in curbside systems spend more time driving and compacting and less time idling, they consume slightly more fuel per day than trucks in backyard systems. The curbside trucks, however, serve more homes and collect more tons per day, and therefore fewer trucks are required. Conversion of three-man backyard systems to three-man curbside systems produces an average saving of 40 percent in fuel consumption (Table

TABLE 16

COST FOR ONCE-A-WEEK COLLECTION USING 2-MAN CREWS, BY POINT OF COLLECTION AND INCENTIVE SYSTEM IN 4 CITIES, 1973*

City	Incentive system	Point of collection	Cost per ton †	Percent difference
1	Task	Curb/alley	$9.53	
2	Task	Backyard	19.26	51
3	8 hours	Curb/alley	8.72	
4	8 hours	Backyard	18.41	55

* ACT SYSTEMS, INC. Residential collection systems. v.1. Report summary. Environmental Protection Publication SW-97c.1. [Washington], U.S. Environmental Protection Agency, 1974. 106 p.

† Labor rates for the cities have been normalized to permit intersystem comparisons; therefore, these figures do not reflect actual collection costs.

TABLE 17

TRUCK AND FUEL REQUIREMENTS FOR AN AREA OF 10,000 HOMES, BY COLLECTION FREQUENCY, POINT OF COLLECTION, AND LENGTH OF WORKWEEK *†

	Once per week				Twice per week			
	5-day week		6-day week		5-day week		6-day week	
	Backyard	Curbside	Backyard	Curbside	Backyard	Curbside	Backyard	Curbside
Trucks required	8	5	7	4	12	7	10	6
Gasoline consumed per day if all trucks are gas (gal)	320	200	280	160	480	280	400	240
Diesel fuel consumed per day if all trucks are diesel (gal)	192	120	168	96	288	168	240	144

* GRECO, J. R. Transfer station feasibility is measured against direct haul. *Solid Waste Management*, 17(4):12, 75, Apr. 1974.

† The following is assumed:

(1) In once-per week backyard service each truck makes 260 stops/day.
(2) In twice-per week backyard service each truck makes 350 stops/day.
(3) In once-per-week curbside service each truck makes 450 stops/day.
(4) In twice-per-week curbside service each truck makes 600 stops/day.
(5) Each diesel truck uses 24 gallons of fuel per day.
(6) Each gasoline-powered truck uses 40 gallons per day.
(7) All systems use three-man crews.
(8) All systems use same routing pattern.

17). Change of crew size in addition to change of point of collection would alter productivity and thus affect the savings which could be expected. Changing of routing patterns can also affect the expected saving. For example, a change from two-sides-of-the-street collection to one-side-of-the-street collection could almost double the on-route travel distance and therefore increase fuel consumption per truck.

Effect on Collectors

Due to the greater distances the waste must be carried, backyard collection is physically more demanding than curbside collection. The result is that many backyard collection systems have a difficult time recruiting collectors and have a high turnover rate. In addition, the greater risk of backstrain and the hazards in yards from such things as clotheslines, holes in the ground, objects in the grass (toys, rakes), and dogs, increases the rate of collector injuries in backyard collection systems.

Separation of Wastes

If citizens are required to separate their solid waste, the different classes of waste will normally be collected separately. It is not necessary to use the same point of collection for all waste types; for example, newsprint could be picked up at the curb or alley and other refuse at the backdoor. Because backyard collection costs more and separate collection of reusable items is usually intended to be as self-supporting as possible, curbside/alley collection is recommended for these wastes.

Separate collection of newspapers and other materials will substantially increase fuel consumption, but the energy saved when the materials are recycled (compared to manufacturing with virgin raw materials) typically offsets the additional fuel requirement.

Effects on Residents

In some communities, citizens will express a preference for backyard collection even though it costs more. In these communities, the true cost difference between backyard and curb/alley collection should be calculated and made known so that the effect of choosing the more costly service is well recognized.

In other communities, where curbside/alley service is the custom, the effects of this policy on the aged and handicapped should be examined. In cases where individuals are unable to carry their waste to the curb, special service should be arranged.

CONCLUSIONS

On the basis of increased efficiency and productivity, fuel conservation, better labor force stability (less absenteeism and turnover), and reduced injuries to collectors, EPA recommends collection from curbside or alleys rather than from backyards. This recommendation is included in the collection guidelines being promulgated by the EPA.

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Frequency of Collection

For health and esthetic reasons, the minimum acceptable frequency of collection for residential waste containing food wastes and other putrescible material is once a week. In certain situations, particularly in inner-city areas, more frequent service is required because of dense population and seriously restricted storage space.

ALTERNATIVES

There are three acceptable choices of collection frequency: once a week, twice a week, and more than twice a week. It is estimated that 50 percent of the urban systems have once-a-week service. They are concentrated on the West Coast, the Midwest, and the Northern States. Systems with twice-a-week collection are primarily in the Southern (especially Southeastern) States and account for approximately 45 percent of the urban systems. More frequent service is provided in about 5 percent of urban communities. Sometimes such service is provided only to particularly crowded neighborhoods; some parts of New York City receive daily or twice-daily collection.

COSTS

An increase in frequency of collection will naturally increase costs due to the greater use of labor and equipment. A comparison of collection costs for four cities shows that savings of 13 to 39 percent may be made by collecting once a week rather than twice a week (Table 18).

ADVANTAGES AND DISADVANTAGES

The primary advantage of once-a-week over twice-a-week collection is that it costs less and uses less fuel. For relatively efficient systems, 23 to 33 percent fewer vehicles are required for once-a-week collection. Fuel consumption is about 30 percent less. The reduction in trucks, manpower, and miles driven can cut costs by as much as 50 percent.

The advantage of more frequent collection is that it reduces littering in urban areas and reduces the amount of space required for storing solid waste.

OTHER CONSIDERATIONS

Fly Generation

Studies in California have shown that frequency of collection can be an important factor in the control of flies, with twice-a-week collection more effective in fly control than once-a-week collection. However, control of flies is more closely linked to proper selection and maintenance of storage containers than to frequency of collection. Use of proper containers to retard fly production

TABLE 18

COST OF CURBSIDE COLLECTION BY FREQUENCY OF COLLECTION AND CREW SIZE, IN FOUR CITIES, 1973*†

City	Crew size	Frequency of collection	Cost per ton ‡	Percent difference
1	1	1	$8.29	39
2	1	2	13.48	
3	3	1	12.82	13
4	3	2	14.67	

* **ACT SYSTEMS, INC.** Residential collection systems. v.1. Report summary. Environmental Protection Publication SW-97c.1. [Washington], U.S. Environmental Protection Agency, 1974. 106 p.

† Using task incentive system.

‡ Labor rates for the cities have been normalized to permit intersystem comparisons; therefore, these figures do not reflect actual collection costs.

makes once-a-week collection of garbage acceptable.

Separation of Wastes

When citizens are required to separate their solid waste, a frequency should be set for each waste category. For instance, newsprint may be collected once a month, while other household refuse is collected once a week. Each decision on frequency should be made independently, taking into consideration the characteristics and storage requirements of each waste type.

CONCLUSIONS

In determining frequency of collection, the following major factors must be taken into account: sanitation, collection costs, fuel consumption, and the storage facilities available to the residents. In old, crowded inner-city neighborhoods, for example, the inadequacy of the storage facilities for the amount of waste generated makes relatively frequent collection necessary. The EPA collection guidelines state that solid waste that includes food wastes should be collected at least once every 7 calendar days. Apart from this the guidelines recommend that collection frequency should be the minimum consistent with public health and safety in order to keep down collection costs and fuel consumption. In general, once-a-week collection of combined wastes should be adequate except in certain inner-city areas.

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Storage Containers

To choose the best storage containers for a collection system, the effects on the users, public health, and collection efficiency have to be considered. Proper containers can save collectors' energy, increase the speed of collection, and possibly reduce crew size in some communities. Once selected, the types of containers that residents may use should be defined either by ordinance or regulation, and citizens should be informed of what is expected of them and why.

ALTERNATIVES

There are five main categories of containers:

1. Stationary storage bins are permanent, immovable structures used either to surround another type of container or for direct storage of solid waste.
2. Fifty-five-gallon drums are large, heavy, cylindrical containers, usually having no lids. They are commonly discarded oil or chemical drums.
3. Containers designed for mechanized collection come in a great variety of shapes and sizes and are used with specialized collection vehicles; they eliminate the manual loading of solid waste into the vehicle.
4. Standard, lightweight, 20- to 32-gallon metal or plastic cans are readily moved rigid containers which normally come equipped with lids.
5. Paper and plastic bags are usually used as liners for rigid containers. These are discussed separately, in the next chapter.

ADVANTAGES AND DISADVANTAGES

Stationary Storage Bins

Stationary storage bins (most frequently made of concrete) are inefficient and unsanitary and sometimes constitute a fire hazard. They require the collectors to carry out the time-consuming, hazardous, and costly procedure of shoveling the solid waste out by hand. Usually they are hard to clean out and are not covered properly. Such bins are usually found at apartment buildings and low-income housing projects. A combination of the inadequacies of the bins plus insufficient maintenance or careless use frequently leads to a severe litter problem around the bins.

When the bins are used to house removable containers, the waste is easier to collect but pieces of it usually fall into the bins, and then both the bins and containers must be emptied.

For these reasons it is recommended that the use of stationary bins be discontinued.

Fifty-five-Gallon Drums

A remnant of the backyard burning era, 55-gallon drums continue to be used as waste containers in many areas. Their use causes health and safety problems to the collectors as well as to the general public, and they contribute to lower collection efficiency and higher costs. Most of the difficulty stems from their weight and the absence of lids. The drums themselves weigh 35 to 40 pounds and so can nearly double the total weight usually lifted by collectors. This increases the risk of back injury and muscle strain. The size and shape of the drums also contribute to difficulty in handling: a drum that slips or is dropped can cause serious injury. Also, the drums are rarely covered and so collect rain and snow, adding even more weight. This moisture causes the waste to stick to the drum, requiring manual handling of the waste itself.

Coverless drums also cause health, safety, and odor problems. During the summer months, insects can breed in the waste. If rainwater works its way to the bottom of the drum, the metal eventually rusts through, allowing rodents to feed from the containers. As the rust progresses, sharp edges are formed which can injure the collector as well as others.

Since the drums are heavy, many collectors resort to the hazardous practice of picking out the waste by hand, or they may leave the waste for the next collection.

Because they are inefficient storage containers and could cause health and safety problems, EPA recommends that 55-gallon drums not be utilized as solid waste storage containers.

Containers for Mechanized Collection

Mechanized collection from bulk containers has long been regarded as an efficient and acceptable way of servicing apartment buildings and commercial establishments. Several of the more efficient residential solid waste systems in the United States use clustered storage and mechanized pickup by which more than one residence can be serviced per stop. Scottsdale, Arizona, uses 80-gallon plastic containers for single-family units, and 300-gallon plastic containers in alleys for four units. Both types of containers are emptied mechanically by a vehicle with an arm controlled by the driver, who never has to leave the cab. An interesting sidenote about clustering wastes is that containers for two families are not as acceptable to residents as four-family containers, since in the first case each resident knows whose waste is whose, while in the second, anonymity is preserved. People also tend to oppose even the temporary storage of other people's solid waste on their property.

Where there are proper storage areas and sufficient access space, and economic analysis shows a cost savings could be achieved, mechanized collection should be considered. Further discussion of such specialized collection systems is provided in the chapter, Residential Collection Equipment and Crew Size.

Metal or Plastic Cans

The most commonly used storage container is the rigid galvanized metal or plastic can. These containers are acceptable when they are lightweight, not rusted through or cracked, kept reasonably clean, and have tight-fitting lids. Containers outside the 20- to 32-gallon range are usually not acceptable. Use of many smaller cans at each stop increases the handling time required to load the refuse into the truck while the use of larger or heavier cans increases the weight the men have to lift.

Other Types of Storage

Use of subterranean containers should be discouraged. They are extremely difficult for the collectors to lift out of the ground, and in the winter they can freeze to the ground, making it impossible to collect them. The extra time it takes to handle these containers lessens efficiency and increases costs. Maintaining the pits is difficult. Loose refuse can get down around the can and into the pit, attracting insects and rodents.

Makeshift containers, such as cardboard boxes, can also present problems because of awkward shape or size, or flimsiness, or because they do not tightly enclose wastes. Regulations on acceptable sizes and weights should be set so as to safeguard the collectors and prevent excessive slowdown of the work by the handling of awkward items.

OTHER CONSIDERATIONS

Fly Generation

Control of flies is closely linked to the adequacy of solid waste storage. If the storage containers are kept reasonably clean and have tight-fitting lids, and if all household wastes are kept in such containers, the problem of flies will be minimized.

Separation of Wastes

If the householder is required to separate his solid waste, there may be a significant impact on storage. With the exception of newsprint, which can be bundled and stored without containers, any separation of either food wastes or reusable materials will require extra storage containers and space. This can become a problem if more than two or three categories of wastes are to be stored separately, or if the collection frequency is low, such as once a month.

CONCLUSIONS

Whatever type of storage container is chosen, all solid waste should be stored so that it does not constitute a fire, health, or safety hazard or provide food or harborage for insects or rodents.

For multiunit collection, EPA recommends the use of bulk containers designed for mechanized collection. Individual housing units should use properly maintained, lightweight metal or plastic cans of no more than 35 gallons in volume, or paper and plastic bags as described in the following chapter.

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Paper and Plastic Bags

Collection of residential solid waste is a labor-intensive activity, and the method of solid waste storage used by residents can have important implications for the choice of equipment and crew size used in a system. In recent years, paper and plastic bags have been increasing in popularity both as liners for rigid containers and as storage containers. Household refuse compactors have also recently emerged, as a volume-reducing storage device; these utilize either a plastic or paper bag as a liner.

ALTERNATIVES

Any bag selected to be part of a collection system should meet National Sanitation Foundation standards. For plastic bags, the standards include resin used, strength at folds and seals, film thickness including tolerances, film strength, bag dimensions, weight, and closures. The paper bag standards include material used, adhesives, tape, thread, capacity, and strength. In addition to these standards, the EPA storage and collection guidelines require that plastic bags not be made of polyvinyl chloride, and recommend that they have at least a 2-mil thickness to avoid punctures and tears.

Currently plastic bags are used more frequently than paper bags because they cost less. However, during the 1974 energy crisis many solid waste systems that were dependent on plastic bags, which are petroleum-based products, had difficulty in obtaining them. Because of the general shortage of plastics the industry was able to be selective about what products they would make and who they would sell them to. Because most cities had procurement requirements such as year-long contracts and special specifications, the plastics industry preferred to sell to other customers with more flexible procurement policies. As a result, some cities had difficulty receiving bids for the bags they needed. To prevent this situation from recurring, collection agencies which have bag-dependent systems may have to be more flexible in their bid specifications and allow for contracts with price escalation clauses, shorter-term contracts, and use of standard production-run bags.

ADVANTAGES

Economic Benefits

Bag systems are well accepted by collection workers. Compared to conventional containers, bags are easier to handle and carry, no lids have to be removed or replaced, no time or effort is required to dislodge the contents, no set-back motion is required, and there is less weight to be lifted. The result is faster, more efficient, and less costly service. Even greater collection efficiency can be realized in the collection of solid waste when home compactors are used since the volume of waste has been reduced and there are fewer items to be picked up. Studies show that use of bags can result in collection cost savings of up to 35 percent per service, holding all other system characteristics constant. However, this will often not be sufficient to cover the cost of the bags (at 3 to 5 cents each for plastic bags, 15 cents each for paper bags, or 30 to 42 cents each for compactor bags). The increases in efficiency realized by introducing bags into the system are translated into reduced costs only when they are combined with other cost-saving measures such as reduced crew sizes or a switch from backyard to curbside service.

When used with backyard service, employing either tote barrels or satellite vehicles, bags will help reduce spillage and blowing litter but will not produce adequate cost savings to offset the cost of the bags.

Esthetic Benefits and Convenience to Householder

When additional storage volume is needed, it is relatively easy to use additional bags. The bags are disposable, so containers do not line the street after collection. Bags can eliminate odors and the cleaning of dirty containers. Collection is quieter because noise from handling of conventional containers is eliminated and because the trucks remain on each street a shorter length of time. Because the bags are kept closed, spillage of waste is reduced.

Health Benefits

Flies and other insect pests that breed in wastes can be reduced or held in check because the bag can be closed tightly. Although rats can enter bags, the use of bags will not attract rats to areas free of them.

Bags help minimize the collector's contact with the waste and so with toxic or infectious substances that it may contain, although he must be careful to avoid injury from sharp protruding objects.

Empty bags are practically weightless compared to conventional containers. Less weight to lift should mean a lower incidence of back injuries and muscle strain among collectors and, consequently, less sick leave and reduced medical expenses.

DISADVANTAGES

There are disadvantages to the use of bags as storage containers for solid waste: (1) replacing conventional containers with a sufficient number of bags costs more than continued use of the containers without the bags, and the distribution of the bags costs money (some of these costs can be offset by the savings in collection cost); (2) bags can fail (this can be minimized by using reasonably thick bags and by using them sensibly); (3) bags are susceptible to animal attacks (leash laws are an effective preventive measure as far as dogs are concerned); and (4) bags are not suitable for such items as branches, cardboard boxes, heavy objects, or objects with sharp or pointed edges (injuries can occur when sharp or heavy objects are hidden in bags).

OTHER CONSIDERATIONS

In a sanitary landfill, the compaction process rips open the bags, allowing the contained waste to undergo normal degradation. Plastic bags themselves are nonbiodegradable, but this presents no real problem for the following reasons:

1. Settlement of the landfill mass, including the nondegradables, is caused by decomposition of the biodegradables. (This decomposition can result in production of gas and leachate which may require special control measures. Thus, the degradables have a greater potential environmental impact than the nondegradables.)
2. Although the widespread use of bags will increase the amount of material entering the solid waste stream, the in-

crease would be relatively small. A recent study supported by EPA determined that the average weight of solid waste in a plastic bag is about 15 pounds and the bag itself weighs about 0.1 pound. The additional waste load caused by the use of plastic bags is only two-thirds of 1 percent based on total weight. Another measure of the effect of plastic bags is the increase in nondegradable waste. For typical residential waste (about 27 percent nondegradable), the increase would be about 2.5 percent. The same study determined the average weight of residential solid waste in paper bags to be about 20 pounds, while the bag itself weighs about 0.5 pound. The additional waste load caused by the use of paper bags is less than 3 percent by weight.

Paper and plastic bags are reduced to harmless products of combustion when burned in a properly designed and operated incinerator. Plastic storage bags currently do not contain polyvinyl chloride (PVC). This material should not be used in the manufacture of bags because of the potential to produce hydrogen chloride when burned, with resulting corrosion of incinerator equipment. In general, polyethylene and paper yield water and carbon dioxide when incinerated in the presence of an abundant oxygen supply.

CONCLUSIONS

Properly designed and manufactured paper bags, plastic bags, and paper bags with plastic liners are acceptable as storage containers for residential solid waste. Plastic bags should not contain polyvinyl chloride, should have a minimum thickness of 2 mils, and meet all other National Sanitation Foundation standards. The advantages and benefits from their use far outweigh their few disadvantages. Paper and plastic bags offer economic and sanitary advantages which make them superior to rigid containers; they present no significant problems when placed in a sanitary landfill or when burned in a properly designed and operated incinerator. EPA supports their use.

Solid waste put through a home compactor presents no significant problems in collection or disposal. The advantages of the home compactor for improving collection efficiency and as a household convenience are evident. However, considering the cost of the machines, the energy and materials expended in their manufacture, and the electrical energy required to operate them, any net economic advantage resulting from their use is certainly not as clear as it is in the case of using paper or plastic bags alone.

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Collection of Bulky Items

Collection of bulky items such as large appliances, furniture, and tree stumps can be a problem in many places; often separate procedures are needed for their collection.

ALTERNATIVES

There are four methods of providing for bulky item collection:

1. Bulky items are collected along with other refuse using compaction vehicles and regular crews.
2. The homeowner calls the collection agency to request that the item be picked up, and the agency sets the date it is to be collected by a separate bulk-pickup crew.
3. Bulky items are collected periodically along defined routes comparable to the regular solid waste routes. Bulk collection is scheduled to cover the whole city in a designated time period, usually 1 week.
4. The resident sets out the bulky item, the regular refuse collection crew reports it, and it is picked up by a separate bulk-pickup crew.

ADVANTAGES AND DISADVANTAGES

Collection with Other Refuse

This system requires that the compaction vehicles be capable of handling the items and that the crew be able to lift them. It would not be feasible for one man operating a side-loading vehicle to collect a refrigerator. But the task would be a reasonable one for men using a rear-loading truck having a large enough hopper. The primary advantage of this system is that it is more economical than having a separate crew to collect bulky items. A disadvantage is that it does not lend itself to the charging of a fee for bulk pickup.

Request or Call-in System

This system has several advantages. The collectors need only go where there are pickups to be made, and proper scheduling makes it possible to concentrate pickups in compact areas. The result is an efficient system with good utilization of the collector's time. A pickup fee may be incorporated very easily. However, this system has serious drawbacks in inner-city areas where there are a large number of items set out to be collected and a lack of cooperation by the residents in requesting pickup.

Periodic Bulk Collection along Defined Routes

This system works very well in inner-city areas where there are many pickups close together. But in areas where pickups are more scattered, this system can be wasteful since collectors must traverse streets where there is nothing to collect. Therefore the efficiency varies according to the type of district in which it is used. A disadvantage of this method is that it is difficult to assess fees for the service. Bulk collection days should be scheduled at a minimum of once every 3 months.

Collection Crews Report Items, Separate Crew Collects

This alternative requires the use of radio communication, otherwise bulky items could sit outside for more than 1 day. Also, the sporadic reports from the refuse collectors are not likely to result in efficient routing of bulk-pickup vehicles. However, this system does insure the pickup of all bulky items.

CONCLUSIONS

The selection of the method of bulky item collection must be based upon the characteristics of the overall solid waste collection system (crew size and truck) and the nature of the area being served (inner city or suburban, and income level). In any case, it is a service which must be provided.

Citizens should be advised of the need to remove all doors from large household appliances to prevent the possibility of a child becoming trapped.

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Source Separation and Collection of Paper

Materials can be recovered from waste for recycling through "source separation." Source separation is defined as the setting aside of recyclable waste materials (such as paper, glass, and metal containers) at their point of generation (the home, office, or other place of business) by the generator. This separation is followed by transportation of the recyclable materials from their point of generation to a secondary materials dealer or directly to a manufacturer. Transportation may be provided by the generator, city collection vehicles, private haulers, scrap dealers, or by voluntary recycling organizations.

Source separation followed by regular municipal or private collection has been used widely for recovery of wastepaper. Recovery of glass and cans by this method has been tried in only a few communities and then on a monthly basis; the economic balance of these systems has been poor to date. EPA is currently in the process of developing a system in which several recyclable elements of household waste will be source separated and then collected simultaneously every week by means of a compartmentalized truck. The projected economics of this system appear to be excellent, and it will be demonstrated and evaluated in 1976. As most of the data on actual programs relates to paper at this time, only the methods of separately collecting paper are discussed here.

Source separation of paper is feasible primarily for newspapers from homes, corrugated containers from commercial and industrial establishments, and printing and writing papers from offices. It is at these points that recyclable grades are generated in a relatively homogeneous and concentrated form. Since the latter two situations are typically handled by private haulers who collect commercial and industrial wastes, a municipal government is mainly concerned with source separation of newspaper by residents. From 1970 to 1974, a period of rising wastepaper prices as well as increased environmental awareness, the number of cities with separate paper collection programs rose from 3 to around 135. In cases where an appropriate market exists, mixed paper from residences can also be separated and collected with the newspaper.

QUANTITY OF PAPER OBTAINABLE THROUGH SOURCE SEPARATION

Paper makes up a large part of the average municipal solid waste stream—about a third by weight (Table 19). Municipal solid waste is generated at an estimated rate of 3.52 pounds per person per day. By using the national estimates for waste composition,

TABLE 19

COMPOSITION OF MUNICIPAL SOLID WASTE, AS DISCARDED, UNITED STATES, 1973*†

Component	Amount (millions of tons)		Percent of total	
Paper		44.2		32.8
Newspaper	8.0		6.0	
Corrugated	11.8		9.0	
Office paper	5.4		4.0	
Other	19.0		14.1	
Glass		13.2		9.9
Ferrous metals		11.0		8.2
Nonferrous metals		1.4		1.0
Food waste		22.4		16.6
Yard waste		25.0		18.5
Other		17.2		12.8
Total		134.8		100.0

* SMITH, F. A., U.S. Environmental Protection Agency. Unpublished data.

† Includes wastes generated in households, commercial and business establishments, and institutions (schools, hospitals, etc.); excluded are industrial process wastes, agricultural and animal wastes, construction and demolition wastes, mining wastes, abandoned automobiles, ashes, street sweepings, and sewage sludge. Wastes now being recycled are also excluded.

a city can roughly estimate the quantity of materials which might be recovered through its source separation program. Specific generation and composition data for a given city would permit a more accurate prediction.

The amount of discarded newspaper varies from house to house, neighborhood to neighborhood, and city to city. This variation is related to such factors as individual household purchasing habits, size and number of newspapers published in a particular area, and the socioeconomic level of the residents. The waste newspaper generation rate in a high income neighborhood may be two or three times that of medium-to-low-income neighborhoods in the same area.

Newspapers comprise about 18 percent of discarded paper and about 6 percent of total municipal solid wastes, according to the national estimate. For a city of 100,000 population with a 50-percent participation rate, the approximate quantity of recoverable newspapers can be determined as follows: 100,000 persons × 3.52 lb per person per day × 0.06 × 0.5 = 10,560 lb, or about 5 tons per day. At a price of $15 per ton, the weekly revenue would be $525.

METHODS OF SEPARATE PAPER COLLECTION

There are two basic methods for separate paper collection presently in use. The most common system utilizes separate vehicles to collect the paper, while the other uses a rack attached to the regular refuse collection vehicle.

Separate Truck System

Trucks. Standard packers, usually taken from the standby fleet, are the vehicles most commonly used for separate collection. Vans and open-bodied trucks may also be used, although they are more expensive to operate than a standard packer because they require an extra crew member to stack the paper inside the truck.

Crew Size. One man for a side-loading packer and two for a rear loader are sufficient to collect paper. As noted above, a third worker is needed if trucks other than packers are used. Because of the higher cost of backyard collection, curbside or alley collection is generally used in these programs.

Routing. The paper collection vehicle can cover three to five normal collection routes each day. This is due to such factors as: fewer items to handle per stop, no requirement to return containers to the curb, usually less than 100 percent participation, and the fact that even households that participate may not do so every collection day.

Unloading Point. If the wastepaper dealer is within a reasonable distance, the truck can unload directly at his facility. Paper dealers in distant locations usually place a large van at the transfer station or disposal site; the paper is loaded into this van, which remains at the site until it is full, at which time the dealer removes it and replaces it with another.

Frequency of Collection. Collections are usually monthly, every 2 weeks, or weekly. EPA data indicate that the overall level of participation, and thus the total quantity of paper collected, will be greater for programs that collect weekly or every 2 weeks than for monthly collection programs. Collection costs are correspondingly higher, however.

Standardization of Collection. To achieve maximum cooperation from the householder, collections must be conducted on a regular basis. Also, citizens must be fully informed of what is expected of them (e.g., newspapers to be wrapped with twine or placed in paper grocery sacks, etc.) and when the truck will be there.

Capital Investment. Capital is required only for any additional collection vehicles required by the program. Actual case studies conducted for EPA found that only 1 of the 10 cities studied actually purchased a vehicle (a small, used packer in this case) for their program. Most of the vehicles used for separate collections have been either standby packers normally used when a breakdown in the regular fleet occurred, older trucks retained after new packers were purchased, trucks no longer needed regularly because of more efficient routing, or other trucks not fully utilized.

Two communities that regularly collected refuse 4 days a week instituted separate collection on the 5th day using the same trucks used in their regular collection. In the cities studied, the institution of separate collection resulted in increased utilization of existing equipment rather than the purchase of new equipment. The fact that this form of resource recovery can often be implemented with little or no additional capital investment is one of its most appealing aspects.

Maintenance, Operating, and Overhead Costs. When a vehicle is used for separate collection, these costs are incurred just as they are for any collection operation. In addition, the costs for establishing and maintaining public participation by means of a public information program must be taken into account.

Labor. Separate collection requires that more hours be spent on the collection route. In all but 2 of the 10 cities studied, however, no additional labor was hired to implement separate collection. In these two cities, part-time personnel were employed for periods of heavy volume. It should also be noted that in every case studied, three-man crews were used only because it was standard collection practice to have three-man crews. As noted above, two-man crews are sufficient for paper collection. The additional labor—and its cost to the cities—would have been considerably less had they not included this unneeded crewman.

Rack System

The rack, or "piggyback," system of separate collection has been used by a private collector in San Francisco since 1962, but its use in Madison, Wisconsin, has received the most publicity. There, piggyback collection was instituted by the city in cooperation with the Paper Stock Conservation Committee of the American Paper Institute.

Truck Modification. To employ this system, a rack is installed beneath the body of a standard packer (Figure 3). The racks vary in size from ½ to 1½ cubic yards. Because of placement of auxiliary gas tanks and hydraulic equipment, not all packer trucks can be fitted with this type of rack.

Collection Procedures. As in the separate truck method, bundled newsprint is placed at the curb. Collection of mixed paper by this method is not recommended due to the space constraints of the racks. A major advantage of the rack system is that the householder need not be concerned with which day is paper collection day. The bundled paper is placed next to mixed refuse containers on any normal pickup day. Refuse and paper are thus collected simultaneously.

Overloading. Compared with separate truck collection, the rack method has apparent advantages in that the route must be covered only once, when regular collection is performed. A drawback is the tendency of the racks to fill up before the body of the truck does. In Madison, with a 60-percent participation rate (i.e., about 60 percent of the residents place bundled newspapers at the curb on any given collection day), the crews must off-load the paper bins one or two times before the compactor body is full. To accomplish this with the least delay, the public works department stations bulk containers at strategic points in the collection

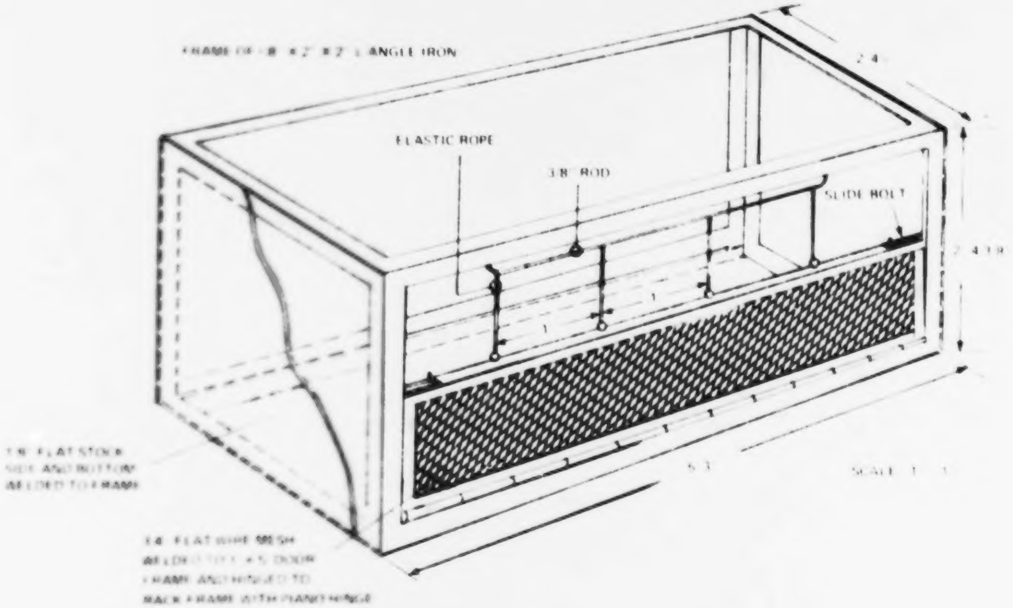
FRAME OF 1/8" × 2" × 2" L ANGLE IRON
ELASTIC ROPE
3/8" ROD
SLIDE BOLT
2'4"
2'4 1/8"
6'3"
SCALE 1" = 1'
1/8" FLAT STOCK SIDE AND BOTTOM WELDED TO FRAME
3/4" FLAT WIRE MESH WELDED TO 1" × 5" DOOR FRAME AND HINGED TO RACK FRAME WITH PIANO HINGE

Figure 3. This is an example of a newspaper rack designed for installation beneath a packer truck for the collection of newsprint separately from other residential solid waste. Source: CITY OF MADISON, WIS., DEPARTMENT OF PUBLIC WORKS, DIVISION OF ENGINEERING.

areas. The crews unload the paper into the bulk containers and proceed along the route. Approximately 10 minutes off the route are required for each unloading (driving time plus unloading). Although the amount of time spent in collection has been longer, no overtime costs have been incurred.

New Equipment Developments. Cities and waste haulers are now experimenting with racks designed to hold a greater quantity of newspapers, thus reducing time off the route.

One equipment manufacturer, Maxon Industries, Inc., has designed and is now testing a two-compartment truck for separate collection. The paper compartment is designed to have a capacity of about 3 cubic yards, or 10 percent of the truck's total volume. This compartment is loaded by a hydraulically operated bin located behind the truck's cab. Unloading of the paper is done automatically, after the mixed refuse has been unloaded. The volume of the paper compartment is large enough so that the truck does not have to leave its regular collection route to off-load it. The device is expected to add approximately $2,000 to the cost of Maxon's "Shu-Pak" model trucks.

An elevated rack, developed by Bynal Products, Inc., is being used in Rockford, Illinois. The crew members throw newspapers up into the rack and stow mixed refuse in the main body of the truck. While the size of this rack is larger than the one used in Madison, its main advantage lies in the fact that it need not be manually unloaded. When the rack is filled, the truck backs up to a stationary compactor or bulk bin, the rear wall of the rack is lowered, and the contents are dumped. This reduces unloading time to a minimum.

Such developments, should they prove operationally feasible, could significantly improve the economics of separate collection.

Capital Investment. Costs for materials and installation of the standard, "under-the-truck" rack range from $80 to $250 per rack. Madison's cost of $170 is about average. In addition, when participation reaches 20 to 30 percent, bulk containers may be needed. In Madison, the cost for a bulk container was $550.

Labor. Time-and-motion studies conducted in Madison and San Francisco show that between 10 seconds (Madison) and 14 seconds (San Francisco) are required to pick up and load bundled newsprint at each stop in addition to the approximately 5 to 15 minutes required for off-loading the paper when the racks are filled. In all cases studied, no additional labor costs were actually experienced because employees had not been working a full day in normal waste collection. Nonetheless, either the existing collection system must be able to absorb the additional time needed, or the revenue from the paper and/or diverted disposal costs must offset added labor costs. Additional labor is required also to collect off-loaded newspapers placed in the bulk containers. For Madison, 1 to 3 man-hours per day per truck were required for servicing the containers.

Private Separate Collection

Private collection of wastepaper by a scrap dealer or waste hauler is one of the newer arrangements currently being tried in a number of communities, particularly on the West Coast. This system involves the least amount of time, money, and manpower on the part of the city. For cities which contract for regular waste removal services, private collection of paper may be their only option.

City management may have no involvement at all, as in the case of San Francisco where the private waste hauler carries out all facets of the program. Other communities have decided to share both the responsibility and the income from the program. They request bids from private scrap dealers and waste haulers for the privilege of an exclusive contract to pick up source-separated paper. In return for a percentage of the income, the city usually agrees to support and publicize the program and to prohibit others from removing paper through an antiscavenging ordinance.

Costs

Due to the large number of variables, it is difficult to give meaningful average costs for separate collection. Its economic viability depends to a large extent on such factors as: (1) type of regular collection practiced (i.e., frequency of collection, size of crews, etc.); (2) disposal costs; (3) revenue received for the paper; (4) participation rate of residents; (5) availability of underutilized men and equipment; (6) efficiency with which the separate collection is carried out; (7) extent to which regular vehicles are rerouted to take advantage of reduced volumes of mixed wastes.

Separate Truck Systems. EPA has studied the costs of collecting mixed refuse and source-separated paper in 10 communities utilizing separate trucks for paper collection (Table 20). The analysis included labor, ownership and maintenance of equipment, and overhead costs for both the regular waste collection system and the separate collection subsystem. Credit was given for revenue from the sale of the paper and for a proportionate percentage of the variable disposal cost for landfill and incineration. In cases where the community paid a second party for disposal, the entire unit disposal charge was deducted for each ton of paper sold. Important transportation savings may also result if recovered newspapers are hauled to a nearby off-loading point or market instead of a remotely located disposal facility. These savings were considered where appropriate.

On the basis of the high wastepaper prices of March 1974, the net effect of instituting separate truck collection on overall collection costs in these 10 cities ranged from a decrease of 23 percent to an increase of 4 percent. On the average there was a decrease of about 6 percent. During a low wastepaper market period (April 1973), the effect of separate truck collection in the same 10 cities ranged from an overall collection cost decrease of 4 percent to an increase of more than 9 percent; the average change was an increase of 1.6 percent. Many of the cities experienced little change in overall costs during either period. It should be noted,

TABLE 20

IMPACT OF SEPARATE COLLECTION, USING THE SEPARATE TRUCK METHOD, ON OVERALL RESIDENTIAL SOLID WASTE MANAGEMENT COSTS IN 10 CITIES*

Case study location	Collection and disposal cost per ton prior to separate collection	Collection and disposal cost per ton after implementation of separate collection †			
		Low paper market (average $8 per ton)		High paper market (average $25 per ton)	
		Cost	% change	Cost	% change
Dallas, Texas	$12.10	$11.60	-4.1	$9.30	-23.1
Fort Worth, Texas	13.50	14.10	+4.4	11.80	-12.6
Great Neck, N.Y.	36.00	38.70	+7.5	36.50	+1.4
Green Bay, Wis.	38.70	37.70	-2.6	37.10	-4.1
Greenbelt, Md.	27.20	27.40	+0.7	26.30	-3.3
Marblehead, Mass.	23.10	25.30	+9.5	24.10	+4.3
Newton, Mass.	32.40	32.20	-0.6	31.60	-2.5
University Park, Texas	14.70	14.90	+1.4	13.10	-10.9
Villa Park, Ill.	13.50	13.40	-0.8	12.40	-8.1
West Hartford, Conn.	26.30	26.50	+0.8	25.20	-5.7

* SCS ENGINEERS. Analysis of source separate collection of recyclable solid waste; separate collection studies. Environmental Protection Publication SW 95c.1. U.S. Environmental Protection Agency, 1974. 157 p. (Distributed by National Technical Information Service, Springfield, Va., as PB 239 775.)

† Credit given for diverted disposal costs and revenue generated from the sale of separately collected wastepaper.

TABLE 21

IMPACT OF SEPARATE COLLECTION, USING THE RACK METHOD, ON OVERALL RESIDENTIAL SOLID WASTE MANAGEMENT COSTS IN THREE CITIES*

Case study location	Collection and disposal cost per ton prior to separate collection	Collection and disposal cost after implementation of separate collection			
		Low paper market (average $8 per ton)		High paper market (average $25 per ton)	
		Cost	% change	Cost	% change
Madison, Wis.	$22.30	$22.00	-1.3	$20.50	-8.1
New York, N.Y.†	53.50	53.40	-0.2	53.50‡	0
Sheboygan, Wis.	32.00	31.80	-0.6	31.50	-1.6

* SCS ENGINEERS. Analysis of source separate collection, 1974.

† Queens District 67 only.

‡ The small quantities of newspaper separately collected had an insignificant effect on overall costs.

however, that many of the programs were relatively new and few had been refined to any significant degree. Additional information on case studies and on computer model analysis is available from OSWMP.

Rack Systems. Cost data on rack collection systems from three case studies were compared with the analysis including the same elements described above for the separate truck systems (Table 21). Separate rack collection tended to lower overall collection costs, but the reduction was slightly less than with the separate truck systems. As already noted, the effectiveness of the rack approach depends on the ability of the existing refuse collection system to absorb the incremental time requirements for collection and transfer operations. If the extra time for off-loading cannot be absorbed, an increase in collection costs will result. Based on experience to date, it appears that the specific conditions in each city would dictate the choice between separate truck and rack collection. The ability to fit racks on existing collection trucks, the number of available men and trucks at the city's disposal, and the manner in which collection is carried out would be some of the major factors relating to this choice.

SEPARATE COLLECTION SUCCESS FACTORS

Markets

Shortages of woodpulp, increased wastepaper exports, and other factors created a strong market for used newsprint, corrugated containers, and even mixed paper in 1973. By the end of 1973, prices for wastepaper were at historically high levels. Forecasts by the American Paper Institute predicted a 7-percent increase in domestic consumption of old newsprint from the beginning of 1974 through 1975, a steady but not dramatic growth.

In addition, most observers expected exports of old newsprint to increase, while several domestic paper companies were reportedly considering building mills to make newsprint from old newspapers. Availability of an adequate supply of old newsprint seemed to be their primary concern.

The advent of the recession dramatically altered the booming wastepaper market in the second and third quarters of 1974. The production of such construction materials as roofing felt and wallboard, which utilize wastepaper, slowed with the decline in new home building. Also, the production of boxboard, the largest end-use of reclaimed newsprint, fell some 33 percent between December 1973 and December 1974, in keeping with the general sales decline. Recession abroad caused curtailment of wastepaper exports, compounding the domestic market problems. It is now the consensus of EPA, the American Paper Institute, and various paper-producing industries that wastepaper prices and demand will rise as the economy improves, and then level off.

What is important for the municipal decision-maker in relation to markets is not to try to predict price fluctuations but to determine the minimum price that he can receive and still have a break-even program. He should then negotiate a contract of a year or more duration with that minimum price as a floor. If the price rises above that level, so much the better.

It is incumbent upon any city considering resource recovery, therefore, to conduct a market study as the first order of business. In a small city or suburban community, this may take the form of a few phone calls to wastepaper dealers or to local manufacturers who utilize wastepaper to manufacture such products as boxboard, chipboard, insulation and roofing materials, and newsprint.

These contacts should be followed by meetings with those dealers and manufacturers who show interest in buying the recovered paper. At these meetings, the quality specifications of the buyer, shipping and hauling arrangements, and other requirements which both the city and purchaser must meet can be clarified. Larger cities are advised to conduct a more formal market study, and to seriously consider requesting bids from prospective buyers. To proceed further with the project, cities are advised to procure letters of intent from reputable dealers.

If the results of further investigation into the other aspects of a source separation program are deemed to be positive and the project is approved, it is advisable to enter into a formal contract with the buyers. If possible, the contract should first guarantee that the paper will be purchased for a specified period of time (this is usually 1 year, although some companies have offered contracts of 5 and 10 years); secondly, it should guarantee a minimum or floor price which the city considers reasonable. The price received by the city may float above the floor price and is usually determined by the weekly quotations in *Official Board Markets*. This publication reports wastepaper prices by grade in 12 major cities.

Public Education

The success of a source separation program depends heavily on citizen awareness, cooperation, and concern. None of these is possible without a vigorous public education campaign to explain the goals and methods of the program. Such a campaign should begin well in advance of the institution of the program. Information techniques such as radio and TV spot announcements, newspaper articles and advertisements, posters, door hangers, flyers, and oral presentations are the usual modes of publicity. The active participation of local environmental and service organizations is an excellent means of developing public interest. These organizations can be extremely effective through their contacts with schools and other civic groups. They are usually willing to give speeches, make posters, and conduct door-to-door canvassing at no cost to the city.

Public education must continue after the program is begun. Occasional flyers inserted in public utility bills as well as weekly or monthly newspaper followup articles are recommended. Continued support of citizen organizations is most helpful in sustaining interest and increasing participation. One large eastern city includes information on the program with each house title and lease to assure that new arrivals in the community are informed.

Householder Impact

Home separation is neither expensive nor time consuming for the householder. In a recent study, 15 families kept detailed records of all factors relating to the separation of glass, cans, and newsprint in their homes for a period of 6 weeks. Expenses (twine for bundling, water for washing, etc.) amounted to 2 cents per month per family. The average time spent on these activities was about 15 minutes per week. The separate bundling of newspapers, which is the separation activity that seems most universally acceptable, took only 2.3 minutes per week and required less than 1 cent per month in out-of-pocket costs. A recent survey of housewives' attitudes on solid waste found that 73 percent of those interviewed felt separation would be "easy" to "very easy" for them to carry out.

Scavengers

Due to the value of secondary materials, many cities have experienced difficulties with unauthorized persons picking up source-separated materials before the authorized truck arrives. This does not represent a legal problem for municipalities which have chosen to grant an exclusive franchise to a private firm for waste collection. In such municipalities, sanctions which normally exist to discourage collection by firms other than the licensee may be brought to bear on scavengers. In communities in which such sanctions do not exist, an antiscavenging ordinance should be passed. Judicial precedent indicates that in most States it is permissible for municipalities to grant exclusive contracts for the collection of solid waste and to prohibit collection by all but city employees or licensees. This authority, combined with the municipalities' traditional power to protect public health and safety, should provide a legal basis for such an ordinance.

Antiscavenging ordinances do not preclude volunteer groups from collecting newspapers as one of their traditional revenue producers. If residents prefer to save their newspapers for such volunteer drives, they should not be discouraged from doing so; however, to avoid confusion as to the ownership of the material, accumulated paper for these drives should not be set out at the curb. This distinction can be made clear in the antiscavenging ordinance so that the paper drives of volunteer groups are not threatened.

The antiscavenging ordinance passed in Hempstead, New York, in 1971 has been used as a prototype in many communities. The ordinance states that all waste placed at the curb becomes the property of the city. Stringent fines are imposed upon scavengers. Strict enforcement, particularly at the beginning of a program, is strongly urged. As much publicity as possible should be given to enforcement efforts in order to discourage potential offenders.

Voluntary versus Mandatory Paper Separation

Most separate collection programs are voluntary in that they *request* citizen support. An increasing number of cities, however, are passing ordinances which require separation. A recent study of 17 cities found that mandatory programs received cooperation from 60 percent (average) of the population, while voluntary programs had a participation rate of 30 percent. These numbers are misleading, however, in that most of the systems have only recently begun. Other data from the same study indicate that participation rises over time, and that as these systems reach the 2- and 3-year level, the relative difference between voluntary and mandatory programs will probably diminish.

Pilot Programs

Most programs begin with a pilot area and expand later. This procedure allows the city to adjust gradually to the new system, and to experiment with methods which might reduce costs and minimize risk. It also allows time for the market to adjust to the new source of supply.

The duration of a pilot program should be no less than 6 months. Because waste in our society has been so long ignored, the handling of it is largely a mindless function. Time is needed to change the habits of citizens and to acquire their cooperation in any new program. A 1- or 2-month program will demonstrate little about full-scale economics, because participation will increase over time, with resultant increases in tonnage and revenues. Participation rates of cities at various stages in their programs indicate that rates tend to rise for at least a year (Figure 4). Participation may continue to rise after that if a strong publicity and awareness program is maintained.

CONCLUSIONS

Recovery of secondary materials through source separation and municipal collection on a regular basis is a new phenomenon, having been practiced only in isolated instances until 1970. Since that time, it has grown rapidly as a means of recovering paper—primarily newsprint—from municipal waste.

Separate collection requires careful planning and administration on the part of the city, as well as the cooperation of citizens. Special efforts must be made to educate and inform residents as to the goals and procedures of the program. The public information aspects of the program cannot be overemphasized. A system which is properly sustained through a continuing public education program will attain a growing rate of participation. To date, participation in existing programs that are properly organized, implemented, and sustained has been encouraging.

Cost of separate collection varies considerably from city to city, partly because separate collection is usually implemented to fit in with the collection system that exists. However, the data indicate that, depending on markets for the paper, separate paper collection can be accomplished with little or no increase in costs to a city and possibly even with a net savings. This has been the case even with relatively new systems for which maximum citizen participation and optimal routing have not yet been achieved.

Costs can be reduced by: (1) mounting a good public awareness campaign to increase the participation rate; (2) obtaining an assured market through competitive bidding procedures and contracts; (3) utilizing existing equipment and manpower as much as possible; (4) instituting and enforcing an antiscavenging ordinance.

On the basis of these factors and the experiences of existing programs, it seems reasonable to assert that a revenue of $15 per ton delivered to a nearby transfer point (the floor price) should cover the costs of a newspaper recovery collection program in many instances.

Source separation and collection of newspapers helps to conserve a resource with significant economic value. At the same time, it effectively reduces solid waste quantities.

EPA recommends that communities look into separate collection of paper and that implementation be given serious consideration by any city in which markets are found to exist.

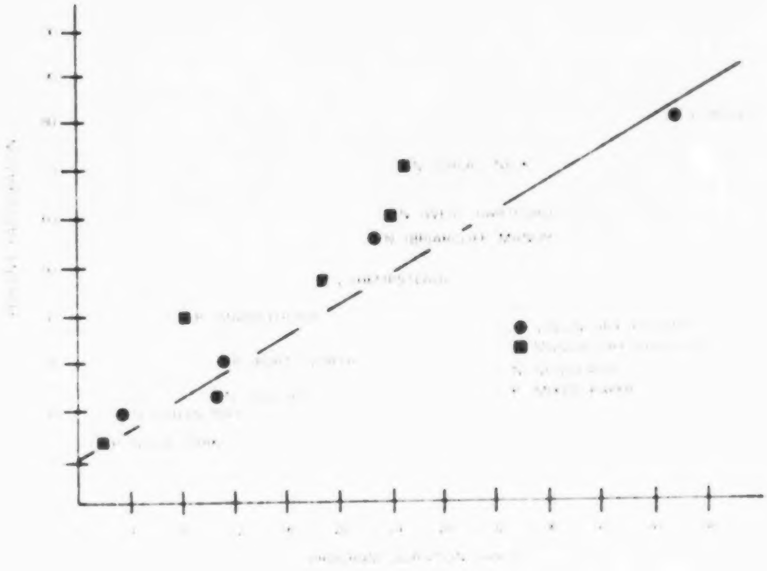

Figure 4. Participation in source separation tends to rise with lengthening program duration. Source: SCS Engineers, Analysis of source separate collection, 1974.

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Residential Collection Equipment and Crew Size

When designing or modifying a collection system, decisions on type of equipment and size of the crews should not be made until the policies on level of service have been established (e.g., point of collection and type of storage containers). On the basis of these policies, preliminary selections can be made. Many other factors, such as round-trip time to the disposal site, street widths, local weight and height limits on vehicles, housing density, labor wage rates, and the amount of waste at each stop, will also have an impact on the decisions concerning the selection of vehicle type and crew size (Table 22). Finally, cooperation from labor and the community are very important in the ultimate success of the system selected.

There are many types of collection vehicles available, some of which are designed for specific jobs. All the collection methods described below use a compaction vehicle to reduce haul cost and prevent the litter problems that often occur with open-top trucks.

ALTERNATIVES

Side Loaders

Most side loaders are in the size range between 13 and 32 cubic yards. Their main use is in collecting from residences and small commercial establishments, but they can also collect from bulk containers. Most bodies manufactured have hopper loading on either side of the vehicle body, although for reasons of safety and convenience the right side is most often used.

Single-family residential curbside service can be most economically provided by a one-man side-loading vehicle with right-hand drive, a low step-in cab, and a separate power source for compaction. In this case, collection should be from one side of the street at a time. This system is best suited for areas with relatively few items per stop and some distance between stops rather than in areas with a high percentage of multiple-family buildings.

High population density areas with more waste at each stop, very narrow streets, and alley collection may be collected with two-man crews using a side-loading vehicle. Both sides of the street or alley are collected at the same time (assuming street width and traffic volume do not present problems).

Rear Loaders

Rear loaders normally range in size from 16 to 25 cubic yards, and, like the side loaders, their main use is in collecting from residences and small commercial establishments although they can also be used with bulk containers.

TABLE 22

RECOMMENDED CREW SIZE AND VEHICLE TYPE FOR RESIDENTIAL SOLID WASTE COLLECTION BY POINT OF COLLECTION AND HOUSING DENSITY

	Housing density	
Point of collection	Suburban	Inner city high-density areas
Curbside/alley	One man using a side-loading right-hand-drive vehicle with a low step-in cab	Two men using a side-loader with low step-in cab or For very heavy waste loads, three men using a rear-loading vehicle with a low step-in cab
Backyard	Two men with tote barrels, using a vehicle with a low step-in cab or Satellite vehicles	Three men with tote barrels, using a rear-loading vehicle with a low step-in cab

High population density areas with more waste at each stop, very narrow streets, and alley collection may be collected with rear loaders and three-man crews (including the driver who also collects at heavy stops). Both sides of the street or alley are collected at the same time (assuming street width and traffic volume do not present problems).

Backyard service in high population density areas containing closely spaced single-family dwellings or a predominance of multiple-family dwellings with short street-to-storage distances should be collected with a three-man crew (including the driver who also collects) using tote barrels and rear-loading vehicles.

Satellite vehicles are sometimes employed in conjunction with rear-loader operations. Where backyard service is provided in medium- and low-density single-family residential areas, the use of satellite vehicles may be economical. These vehicles are usually driven to the area where they will be used each day or they may be towed behind the "mother" truck on a trailer. They may be stored in decentralized garages. The small, usually noncompacting, three- or four-wheeled vehicle is driven up the driveway as close as possible to the waste. When filled, the vehicle is returned to the mother truck for emptying. The selection of a satellite vehicle system rather than tote barrels depends on the accessibility of the waste storage point to the vehicle, the distance from street to storage, and the distance between stops. Another consideration is the availability of a mother truck with a hopper compatible to the hopper of the satellite vehicle when dumping.

Specialized Collection Vehicles

In addition to the more traditional collection truck types, there are many specialized vehicles used today. Some have mechanical arms, such as the "Son of Godzilla" used in Scottsdale, Arizona. Some communities use container trains, which are basically very primitive and inefficient. Still other methods involve the use of multifamily bulk bins to collect residential waste; these methods include the system of alley collection from bulk metal bins used in Odessa, Texas, the "Son of Godzilla," and the barrel-tipper for alley collection used in Tolleson, Arizona. In Covina, California, a one-man mechanical bag collector, the "jumping bean," which shows promise for specific applications, is being developed.

In addition, two types of vehicles generally used for collecting commercial wastes are sometimes used in residential collection. The front-end loader has shown some merit in sparsely populated areas. These trucks, which range in size from 24 to 41 cubic yards, collect from bulk containers usually varying in size from 2 to 10 cubic yards. Trucks with roll-off containers are also used in rural areas for residential collection. The containers are placed at strategically located collection points and are picked up and dumped on a regular basis.

The use of specialized or commercial vehicles under the appropriate conditions can substantially reduce collection costs. Some of these systems require a large initial capital investment, however, and others require extra citizen cooperation.

OTHER CONSIDERATIONS

Many additional factors must be considered before the final decision is made on vehicle type and crew size. For example, crew size selection will be affected by the amount of waste per stop, haul time to the unloading point, wage rates, and labor's preference and persuasion. Preliminary results from an OSWMP safety study show that a large percentage of accidents during collection occur when workers are distracted by conversation among themselves, and this may be a factor in favor of small crews. In high population density areas, the larger quantity of waste at a given stop makes larger trucks with three-man crews economically competitive with smaller crew sizes. Where crew size reduction is a goal, labor's resistance may pose a serious obstacle. Increased wages and labor force reduction through attrition and assignment to other city departments can help smooth the transition to smaller crews.

Vehicle selection is affected by such local factors as haul time to the processing or disposal site, street or alley width and intersection size, types and amounts of waste, and highway load limitations (number of axles required). Haul time is important because time on the route is reduced by the amount of time spent driving to the unloading site. Haul time can be reduced by either reducing the number of trips to the unloading site through increased vehicle capacity or by locating an unloading site closer to the collection area, i.e., setting up a transfer station.

Vehicle size depends partly on street width since narrow streets can preclude large vehicles with wider turning radii. If this is not a problem and there is a long haul time, a larger vehicle is indicated. Tandem axles may be required for vehicles over a given size because of highway load limits, however. Tandem axles have several disadvantages that can increase costs: The vehicles themselves are substantially more costly. They are not designed for the turning and maneuvering most collection vehicles must perform. Therefore, unless these trucks are run in a straight line down the street, their maintenance cost will increase. In addition, they cause more wear on the roads and are more difficult to drive. Overall, these disadvantages may be greatly outweighed by reduced hauling costs, but they must be considered. As a general rule of thumb, when lengthy haul times are not a problem and street widths permit it, a 20-cubic-yard vehicle should be selected. This vehicle size provides the maximum amount of flexibility to handle increasing waste loads and changing disposal site locations without the problems encountered with tandem-axle vehicles.

Other considerations before purchasing a vehicle include overhead clearances under bridges and at the garage, the availability of parts, and warranty service. Also, decisions on such items as transmission and fuel type need to be made. Automatic transmissions are initially more expensive, but over the life of the vehicle the cost of clutch replacement exceeds the initial differential. Also, automatic transmissions are easier to drive and safer in hilly areas.

Currently diesel engines are initially more expensive than gasoline-fired engines, but over the life of the engine the operating and fuel cost savings of the diesel engine exceeds the initial cost difference. Diesel engines also cause less air pollution. One drawback of diesels is that they may be harder to start in cold weather. They are also noisier.

Chassis and body replacement policies should be included in long-term purchase plans. Chassis replacement depends upon engine operating hours, which is related to mileage, and also upon drivers' habits. However, most communities prefer to think in terms of years of use. As a general rule, the chassis should be replaced every 3 to 4 years and bodies every 6 to 8 years. Need for replacement should be calculated for each truck individually, being sure to take into account the cost of downtime for the older vehicles.

Another important consideration before purchase is safety. When the safety standards developed by the American National Standards Institute for rear-loading and side-loading collection vehicles are implemented, all vehicles manufactured will be required to meet rigid safety standards. Adoption and publication of the ANSI standards is expected in the fall of 1975. Compliance is mandatory 2 years from publication, which means the fall of 1977. It is advisable to include in bid specifications the requirement that once these standards are adopted, any vehicle delivered must meet them.

The costs related to collection vehicles are described in greater detail below.

Vehicle Costs

The costs are generally divided into the following categories:

- I. Vehicle capital cost (fixed cost)
  - A. Chassis
  - B. Packer body
  - C. Volume and type of purchase
- II. Operating cost (variable cost)
  - A. Consumables (gas, oil, tires)
  - B. Maintenance and repair (labor and parts)
- III. Overhead cost (fixed cost)
  - A. Insurance
  - B. Registration, license, and permit fees
  - C. Garage (rent and utilities)

For equipment replacement analysis, the cost of downtime from breakdowns should be included, with the fixed and variable costs listed.

Vehicle capital cost is based primarily on the following factors:

- A. Chassis
  - 1. Make (Ford, Dodge, GMC, International, White, etc.)
  - 2. Horsepower
  - 3. Fuel type (diesel vs. gas)
  - 4. Number of axles
  - 5. Other options (automatic vs. standard transmission, power vs. regular steering, power takeoff vs. auxiliary engine, right-hand drive)
- B. Packer body
  - 1. Manufacturer
  - 2. Type (front, rear, or side loader)
  - 3. Capacity (cu yd)
  - 4. Compaction capability (reinforcement and power)
- C. Volume and type of purchase (number of trucks, bid basis)

There are at least 24 manufacturers of solid waste packer trucks: 13 make rear loaders, 13 make side loaders, and 11 make front loaders. There are at least 14 manufacturers of chassis for packer trucks. Considerable ranges are to be found in the prices (Table 23).

Operating costs are based on the following factors:

- A. Consumables: Gas, oil, and tire costs are functions of equipment usage.
  - 1. Gas and oil consumption is more closely related to hours of use than miles. It is affected also by point of collection (backyard vs. curbside), type of collection (residential, commercial, rural), and haul distance to the disposal site.

TABLE 23

TYPICAL RANGES IN PACKER TRUCK PRICES (INCLUDING CHASSIS), 1975

Standard sizes (cu yd)	Prices
Rear loaders:	
16-25	$20,000-$45,000
20*	25,000- 32,000
Side loaders: 16-37	20,000- 38,000
Front loaders: 24-41	35,000- 50,000
Roll-off: 35,000 lb-75,000 lb	30,000- 45,000

* The prices for the 20-cu-yd rear loader are shown separately because of the prevalence of this vehicle size.

2. Tire life is closely related to the vehicle's disposal point. The chance for punctures is greatly increased if the disposal point is at a land disposal site rather than a transfer station or other concrete pad discharge point. Other major factors affecting tire life are total miles driven, condition of roads, and air pressure maintenance.

B. Maintenance and repair costs are related to the effectiveness of the preventive maintenance program, how carefully the packers are driven, and reliability and sturdiness of the equipment (initial cost).

Fuel consumption rates for residential collection are shown below. These figures are based on data for 1 month in 1973, on 24 diesel and 20 gas packers from 11 communities using the EPA Data Acquisition and Analysis Program (DAAP). It should be pointed out that while the figures below indicate that backyard service uses less fuel per hour, that does not mean it is the most cost-effective. In curbside collection, the truck is moving from house to house with much more speed and therefore the hopper must be cleared more frequently. The more frequent cycling of the hopper requires the engine to run at a faster rpm and use more fuel per hour. The cost-effectiveness is shown only when you also take into account the greater number of homes per hour that the same truck can service with curbside rather than with the slower backyard service.

	Gallons per hour
Curbside service:	
Diesel	2.38
Gasoline	2.78
Backyard service:	
Diesel	1.35
Gasoline	1.72

Typical annual costs of operating a 20-cubic-yard, rear-loading diesel packer for curbside residential pickup, averaging 7 hours per operating day, are:

Depreciation ($30,000 at 6 percent interest amortized over 5 years)	$ 6,900
Fuel (at $0.36 gal)	2,180
Oil (engine and hydraulic)	480
Tires	1,680
Maintenance and repair:	
Parts	1,600
Labor	2,400
Insurance and fees	3,000
Total	$18,240

CONCLUSIONS

In summary, the determination of the optimum combination of equipment type and crew size is very complex. There are many dependent variables which impact on the decision. Furthermore, the problem is a dynamic one in the sense that changes in system parameters such as waste generation, traffic congestion, or haul distance may mean there is a new optimum combination. Managers of collection systems must continually review the influencing factors in order to be sure that their current decisions on equipment and crew size are optimal.

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Equipment Systems for Collection of Commercial Wastes

Most public solid waste collection systems handle residential wastes only, but some also handle commercial solid waste (defined as wastes generated by business or industrial establishments and by residential apartment buildings with more than four to six units). The following discussion of equipment systems for collection of commercial waste assumes that the community has sufficient volume of such wastes to justify collecting it separately from residential refuse.

ALTERNATIVES

There are three basic systems for collection of commercial waste. The first is based on the residential-type vehicle—the side or rear loader (see previous chapter on Residential Collection Equipment). Wastes can be fed into the hopper of this type of vehicle either by hand or mechanical dumping devices (Figure 5). Metal bulk containers designed to work with side loaders usually range in size from 1 to 4 cubic yards. Containers used with rear loaders are most commonly 1 to 3 cubic yards in size. Some rear loaders accept larger containers, but they are rarely larger than 8 cubic yards. The containers for both side and rear loaders can be used in conjunction with stationary compactors.

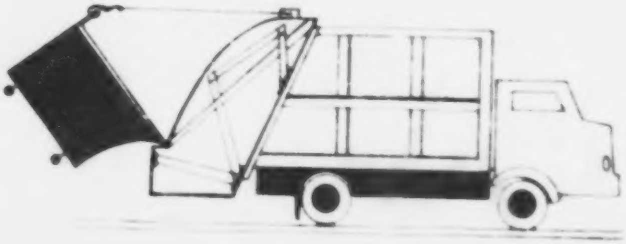

FIGURE 5. Bulk containers can be emptied mechanically into a rear-loading compactor truck (as shown) or a side loader.

The other two systems utilize trucks and containers specifically designed for commercial collection. In one of these systems a front-loading truck lifts metal bulk containers over the front of the truck cab and empties them into the top of the body (Figure 6). The containers range in capacity from 1 to 10 cubic yards. These containers also can be used with stationary compactors.

Unlike the side or rear loader, the front loader is not designed for hand loading. Another difference is that the containers used with front loaders are usually larger and have no casters to facilitate movement to the truck. This means that the container has to be placed so that the truck can be driven to it. The body capacity of the front loader ranges from 20 to 41 cubic yards. It is operated by one man (the driver), and he does not have to leave the cab to carry out the collection.

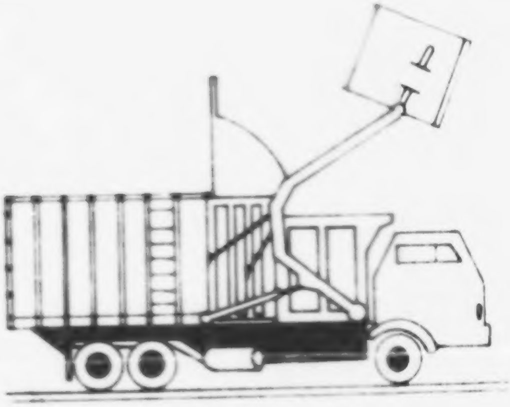

FIGURE 6. The front-loading compactor truck collects waste by picking up bulk containers, lifting them over the cab, and emptying them into the hopper.

The third basic system is the tilt-frame truck with roll-off container (Figure 7). This truck has a pair of guide rails that tilt to facilitate the loading and unloading of a boxlike container. The containers may be open-top or enclosed. Either type may be loaded by hand, by mechanical devices (e.g., conveyor belt, loader, etc.), or by stationary compactor. When the container is full, it is loaded onto the truck chassis and taken to the disposal area where it is emptied and then returned. A variation of this system is to bring an empty container and swap it for the full container. This does reduce the time needed to service the container but may not always be feasible or desirable. For example, a container may be located in a small alleyway downtown with the disposal site only a few minutes away. All the time gained in not having to make a round trip to the disposal site would be offset by the additional maneuvering needed to effect the swap. Roll-off containers vary in size from 10 to 55 cubic yards. This system, like the front-loader system, is a one-man operation. Although there are other methods of commercial collection for more specialized applications, the three described are the most common.

ADVANTAGES AND DISADVANTAGES

Residential Collection Trucks

Residential-type trucks (rear and side loaders) have some definite advantages over the two purely commercial vehicles. The first is lower initial investment. A side or

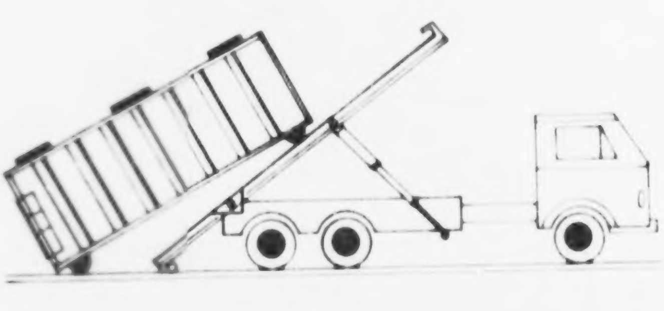

FIGURE 7. Tilt-frame vehicles are used to transport roll-off containers.

rear loader costs about half as much as a front loader. It is also more versatile. Since the truck can be loaded manually or by mechanical devices, a wide choice of storage containers can be used, including bags, 20- to 30-gallon cans, or bulk containers 1 to 8 cubic yards in capacity. Spare equipment can be kept to a minimum because of this system's versatility and compatibility with residential collection, thus helping to reduce overall budget requirements. If there is not at least 500 cubic yards (35 tons) of noncompacted commercial solid waste generated daily, the acquiring of separate commercial collection vehicles would hardly be justified.

The service area is another important consideration. Certain streets and alleyways along collection routes, particularly in central business districts, may not be able to accommodate the larger commercial vehicles. There often is no space for the larger storage containers or for the maneuvering of the truck to pick them up, making the use of side or rear loaders with smaller caster-equipped containers the only solution.

On the negative side, the most important disadvantage of using residential trucks for commercial collection is the relatively high operating cost when large waste quantities are collected. Per ton costs are higher because of lower productivity; this system is much slower, and the capacity of the bodies is smaller, meaning more frequent trips to the disposal site. If mechanical storage containers are used, there are other costs. The containers used with side or rear loaders are generally not made very well and the lids and casters require constant maintenance. Also, these small, unbalanced containers are easily toppled and can cause accidents.

Front-Loader System

This system has many advantages over the residential system. The front loader can handle much more tonnage per man-hour. In an 8-hour work shift, if a rear loader can collect 10 tons, a front loader will collect 20 tons. This is possible because a front loader can dump an 8-cubic-yard container as quickly as a 2-cubic yard container. The same cannot be said for the rear loader with its smaller hopper capacity. The front loader has the advantage of simplicity of design, especially compared to the rear loader, and lower maintenance costs result from the fewer moving parts.

If there is a sufficient quantity of commercial solid waste to be collected, the disadvantages for the front-loader system are minor compared to the advantages. The requirement of space in which to maneuver a big truck to a stationary container is a disadvantage. The high initial investment can be a deterring element. The large chassis size means a more specialized driver must be trained or hired. Satellite services and equipment (container delivery truck, welding and painting apparatus) must be requisitioned. Finally, sufficient backup equipment must be available to assure uninterrupted collection.

Tilt-Frame System

When large volumes of waste occur in each of a number of locations, the tilt-frame or roll-off system may be the most cost-effective. To get full utilization of the system, a container should be emptied at least once each week, and a minimum of four containers should be taken to the disposal site per day. The weekly minimum volume of waste that would justify placing a roll-off container at a given commercial stop would be about 160 cubic yards of uncompacted waste or enough to fill a 40-cubic-yard compactor container. A large, sprawling service area can best be served by the roll-off. Many county governments station roll-off containers as "minidisposal sites" in rural areas rather than provide individual service to residents. Special or short-term cleanup projects also lend themselves very well to this system. And finally, the unit can be versatile—different containers make the vehicle a dump truck, leaf collector, sludge hauler, snow-removal apparatus, liquid wastes truck, and heavy bulk debris truck. There is even one type of roll-off that can be converted to a front loader.

The disadvantages are the high initial equipment costs for limited applications, need for special driver experience and skills, and the large maneuvering area required.

This system also has very little compatibility with the other two systems. A rear loader or front loader could not fill in if there was a 40-cubic-yard container full of debris that had to be moved, and the roll-off truck was not available. The reverse is also true—the roll-off truck could not collect on a route normally serviced by a rear loader or front loader. The roll-off system also requires a large storage area for spare containers and support equipment.

COMPARATIVE COSTS

By making certain assumptions, costs of the three systems can be compared on a per ton basis (Tables 24–26).

For the rear loader, it is assumed that a two-man crew manually collects two loads a day, 5 days a week, working 8 hours per day. The truck's capacity is 20 cubic yards, and it compacts to an average density of 500 pounds per cubic yard (4-to-1 ratio). On this basis, the estimated total yearly cost, including the cost of the truck, labor, overhead, maintenance, fuel, insurance and licenses, would be $49,478, or $19.03 per ton (Table 24).

TABLE 24

TYPICAL YEARLY COSTS FOR COMMERCIAL COLLECTION WITH REAR LOADER AND 2-MAN CREW*

Item	Cost per year
Truck cost ($30,000 at 6 percent interest amortized over 5 years)	$6,900
Labor, including 20 percent fringes:	
Driver ($5.00/hr)	12,480
Helper ($4.50/hr)	11,232
Consumables:	
Fuel (7,200 gallons × $0.36)	2,592
Oil	480
Tires	1,680
Truck maintenance	4,000
Management and administrative overhead (30 percent of direct labor)	7,114
Miscellaneous (insurance and fees)	3,000
Total	$49,478

$49,478 ÷ 2,600 tons/year† = $19.03/ton

* Costs are for a 20-cubic-yard packer that is manually loaded. Average compacted waste density is 500 lb/cu yd, and two loads are collected each day.

† 20-cu-yd body × 500 lb = 10,000 lb, or 5 tons; 5 tons × 2 trips/day = 10 tons per day; 10 tons/day × 260 days = 2,600 tons per year.

To estimate costs for a front loader, the following assumptions were made: 2.5 loads per day, 5 days a week, and 8-hour work shifts; an average of six containers are emptied per hour; the average container size is 6 cubic yards; the body capacity is 30 cubic yards, with a 4:1 compaction ratio; and the average weight per compacted cubic yard is 500 pounds. The initial investment in the storage containers is assumed to be covered by a rental fee or sale to the users. On this basis, the yearly operating cost is $48,993, or $9.92 per ton (Table 25).

The assumptions underlying the cost estimates for the roll-off system are as follows: 5 loads per day, 5 days a week, in 8-hour work shifts. The average container size is 30 cubic yards, and the average density of the compacted waste is 500 pounds per cubic yard. The cost of the containers and/or compactors is assumed to be passed on to the user and is not considered as part of this estimate. With these assumptions, the yearly operating cost of the roll-off truck is estimated at $44,293, or $4.54 per ton (Table 26).

The roll-off system, with a cost per ton of $4.54, is clearly the most cost-effective. The next most cost-effective system is the front

TABLE 25

TYPICAL YEARLY COSTS FOR COMMERCIAL COLLECTION WITH FRONT LOADER AND DRIVER-OPERATOR*

Item	Cost per year
Truck cost ($50,000 at 6 percent interest amortized over 5 years)	$11,500
Driver's wages and 20 percent fringes ($6/hr)	14,976
Management and administrative overhead (30 percent of direct labor)	4,493
Truck maintenance	10,200
Fuel (8,400 gallons × $0.36)	3,024
Insurance and licenses	4,800
Total	$48,993

$48,993 ÷ 4,940 tons/year† = $9.92/ton

* The truck is a 30-cu-yd packer; the average waste density is 500 lb per cu yd; and 2.5 loads are collected each day.

† 30-cu-yd body × 500 lb = 15,000 lb or 7.5 tons; 7.5 tons × 2.5 trips per day = 19 tons per day; 19 tons per day × 260 = 4,940 tons per year.

TABLE 26

TYPICAL YEARLY COSTS FOR COMMERCIAL COLLECTION WITH TILT-FRAME (ROLL-OFF) TRUCK AND DRIVER-OPERATOR*

Item	Cost per year
Truck cost ($40,000 at 6 percent interest amortized over 5 years)	$9,200
Driver's wages and 20 percent fringes ($6/hr)	14,976
Management and administrative overhead	4,493
Truck maintenance	7,800
Fuel (8,400 gallons × $0.36)	3,024
Insurance and licenses	4,800
Total	$44,293
$44,293 ÷ 9,750 tons/year† = $4.54/ton	

* The truck takes on a 30-cu-yd container; the average density of the compacted waste is 500 lb per cu yd; and five loads are handled per day.

† 30-cu-yd body × 500 lb = 15,000 lb or 7.5 tons; 7.5 tons × 5 trips per day = 37.5 tons per day. 37.5 tons per day × 260 = 9,750 tons per year.

loader with a cost of $9.92 per ton. The least cost-effective system shown is the rear loader with a cost of $19.03 per ton. It should be noted that the costs of operating a residential-type truck (rear or side loader) with mechanically emptied bulk containers would fall somewhere between those for the front-loader system and the manually loaded rear-loader system on a per ton basis. The more bulk containers are used with the rear or side loader, the closer its costs will come to those of the front loader, but it can never be quite as cost-effective.

CONCLUSIONS

If a community has commercial solid waste to collect, a thorough analysis has to be made to determine which collection system is best suited to its needs. The volume of commercial solid waste is the main criterion. Without sufficient amounts of wastes to justify purchase of a commercial system, it would be more cost-effective to collect the commercial waste with the residential collection equipment. Unfortunately there is no rule of thumb for deciding when a switch in collection methods should be made. It is simply a matter of which system or combination of systems is the most cost-effective for each community, and this can be determined by cost accounting.

The system to be utilized is dictated by several important criteria in addition to waste volume and cost-effectiveness. The service area must be surveyed to assure that the equipment can be safely used on the roads, streets, and alleyways without damage to structures or equipment. Other factors include the type and size of storage facilities needed and distance between the service area and the disposal site. The wishes and reactions of users of the service and the collection workers must be given careful consideration in the decision-making.

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Rural Collection

The collection methods used in urban areas have little applicability to rural areas because of the much greater distance between stops. However, there are techniques available for rural collection, and local officials must decide which of these best suits their situation.

ALTERNATIVES

Four techniques can be used for solid waste management in rural areas. These are: disposal of waste on one's own property, direct haul by the resident to the disposal site, the use of centrally located bulk containers, and house-to-house "mailbox" collection of solid wastes.

Each of these systems requires citizen cooperation. Some States empower local authorities to require mandatory solid waste collection throughout their jurisdiction. In these areas, the governing agencies must provide adequate service, and residents must accept and pay for the service. Exceptions are allowed where the householder can prove that he is privately disposing of his waste in a satisfactory manner, usually by burying the waste on his property in a location approved by the governing agency.

There are three requisites for instituting mandatory collection: State enabling legislation must exist to allow local government agencies to enact ordinances requiring mandatory collection; an economically feasible system must be available to provide collection service to all residents; and governing agencies must be available to operate the system. Legal, political, or economic reasons often preclude mandatory solid waste collection in rural areas even though it might be desirable. The logical alternative is a voluntary system. A mandatory system will theoretically collect 100 percent of the residential solid waste generated within a political jurisdiction, whereas a voluntary system may collect much less. The real crux of the matter is whether the resident is required to pay for solid waste collection service or not. Voluntary acceptance of charges for solid waste collection should not be expected from a large percentage of the population.

Although data on collection costs are not generally available for rural systems, a total operating cost of $7 to $15 per ton can be anticipated for the average bulk container collection system.

ADVANTAGES AND DISADVANTAGES

Disposal by Residents

The simplest method is the direct disposal of wastes on one's own property. It provides the least service at the least expense to the rural government. However, it is the system that is the most difficult to monitor and control. It also encourages roadside dumping as well as open burning, which are unacceptable practices. In order to be successful, an extensive educational campaign is needed to ensure proper disposal of wastes.

Hauling by Residents to Landfills

The direct haul of wastes by the resident to a central sanitary landfill eliminates some of the problems associated with disposal of wastes on one's own property. The distance to the landfill may discourage some residents from using it regularly, however. Roadside littering as well as traffic at the disposal site may also create problems.

Bulk Container System

In a bulk storage container system, a number of containers, enough to serve the needs of the rural population, are strategically located along highways or roads easily traversed by a collection vehicle. The individual resident is required to transport his waste to the bulk containers, which are serviced by collection vehicles; the collected wastes are transported to a central sanitary landfill or processing facility.

There are two different types of bulk storage container systems. In one system, the containers are boxes with lids or doors ranging in size from 3 to 8 cubic yards and serviced by emptying into a collection vehicle. The other type of bulk container system uses large open boxes with a capacity of approximately 20 to 40 cubic yards. These large boxes are not emptied, but instead are replaced regularly by empty boxes, with the full boxes being taken directly to the processing or disposal site.

There are three basic types of bulk bin collection vehicles: front-loading, rear-loading, and side-loading, each with its own characteristics and capabilities (Table 27).

TABLE 27

CHARACTERISTICS OF RURAL BULK BIN COLLECTION SYSTEMS BY TYPE OF VEHICLE USED*

Item	Vehicle type		
	Front loading	Rear loading	Side loading
Crew size	One driver-collector	One driver, one to three collectors	One driver, one or two collectors
Typical container servicing time	1 to 2 min	2 to 6 min (includes some litter cleanup)	1 to 3 min (includes some litter cleanup)
Container site development	Requires pull-off area from main road, with gravel or paved surface common	Requires area in which to back up to container; gravel or paved surface is common	If users and collection vehicle can stop safely along road, site needs to be only slightly larger than containers; otherwise pull-off area is common with gravel or paved surface
Container sizes	0.8 to 8 cu m (1 to 10 cu yd)	0.8 to 4.5 cu m (1 to 6 cu yd)	0.8 to 3.1 cu m (1 to 4 cu yd)
Site maintenance	Usually a special crew cleans sites periodically	Collection crew cleans up as containers are emptied	Collection crew cleans up as containers are emptied
Typical packer body sizes	15.3 to 30.2 cu m (20 to 40 cu yd)	12 to 22.7 cu m (16 to 30 cu yd)	9.9 to 24.5 cu m (13 to 32 cu yd)
Types of wastes collected	Any wastes that will fit inside container	Any wastes that will fit into rear-loading hopper	Any waste that can be placed through the side doors
Vehicle flexibility	Can service only front-loading containers	Can service both rear-loading containers and house-to-house collection	Can service both side-loading containers and house-to-house collection

* GOLDBERG, T. L. Improving rural solid waste management practices. Environmental Protection Agency Publication No. SW-107. Washington, U.S. Government Printing Office, 1973. 83 p.

A slight variation of the bulk bin collection system has been demonstrated in Lee County, Mississippi, where wheel-and-axle-mounted 5-cubic-yard mobile waste containers are utilized. Because many of the smaller secondary roads and bridges were not designed to carry as much weight as that of a large packer truck, a conventional stationary waste container could not be used. However, by towing the mobile containers with a pickup truck to a major road, they can be emptied by the packer truck. Other areas of the county with better roads are able to use standard stationary containers.

In calculating the bulk container capacity required for an area, it may be useful to consider that the average number of persons served per cubic yard of bulk container space, based on figures from selected areas, is 10.1 for once-a-week collection (Table 28). However, the ratio of persons per cubic yard varies widely depending on local conditions. To determine the number of containers that can be emptied into a collection truck, the following estimates can be used. For loose solid waste, a density in the container of 75 to 150 pounds per cubic yard can be expected. A density in the col-

TABLE 28

EXAMPLES OF RURAL SOLID WASTE COLLECTION EQUIPMENT SYSTEMS

Location	Estimated population	Number of containers	Size of container (cu yd)	Collections per week	Number of persons per cu yd storage	Number of trucks	Size of trucks (cu yd)	Initial capital cost *
Baldwin, Co., Ala.	47,000	†		1		14	16-23	$240,000‡
Chilton Co., Ala.	17,000	91	4	3	16	2	30	68,000
Choctaw Co., Ala.	14,000	†		1		3	20	48,000
Coffee Co., Ala.	14,000	170	4	1-2	14	1	30	62,700
Macon Co., Ala.	13,800	137	4	1-2	17	1	30	55,900
Madison Co., Ala.	40,000	†		1		9	23	106,000
Tuscaloosa Co., Ala.	50,000	335	5-6	2	7	5	30	310,000
Clark Co., Ark.	11,702	142	3, 4, 6	3	6	1	30	76,058
Humboldt Co., Calif.	10,000	20	8	2	12	1	42	221,849
		2	20			1	roll-off	
		5	40					
Evans Co., Ga.	7,290	10	3	2-3	9	2	23	60,695
		70	4					
Grady Co., Ga.	10,000	126	4	2	10	1	20	49,787
Screven Co., Ga.	9,500	146	4	2	7	1	25	66,000
Benewah Co., Idaho	3,680	14	§12	2	11	1	20	†
Bonner Co., Idaho	3,000	39	10	2	4	1	20	38,400‡
Boundary Co., Idaho	2,300	17	10	2	7	1	20	17,540‡
Kootenai Co., Idaho	2,250	10	§10	2	3	1	10	50,900‡
		20	§12			1	16	
						1	20	
Shoshone Co., Idaho	1,016	11	§4	1-2	4	1	16	‡
		12	§12				20	
DeSoto Co., Miss.	50,000	72	6	2	26	1	30	‡
		78	4			1	roll-off	
		7	30			1	roll-off	
Lee Co., Miss.	17,218	97	6	2-3	17	2	30	141,200
		70	¶5			**		
Humphreys Co., Tenn.	8,796	134	6	2	4	2	31	105,465
		23	8					
Jefferson Co., Tenn.	17,014	128	4	2	14	1	30	68,310
		17	6					
Polk Co., Texas	9,500	110	4	3	5	2	30	93,086

* Data were gathered in 1974 but capital costs vary from 1968 to 1973.
† Mailbox system.
‡ Contracted.
§ Hand unload.
¶ Mobile containers.
** Three pickup trucks for towing containers.

lection vehicle of 450 to 1,000 pounds per cubic yard of compacted waste can be expected. Data on the density that can be achieved by any specific type of collection truck can be obtained from a list of specifications for that model or the dealer.

Site locations should be chosen according to commonsense criteria. For example, containers should be located so that they will be on the way for users going to town, church, or school. Containers should be located with regard to where the people are. The maximum distance of a container from any user should not be over 3 to 5 miles. If containers are placed near existing dumps, they are more apt to be successful because of the strength of habit of the users.

The climatic conditions and terrain of the area will affect the cost of establishing container sites. Occasionally a wide fork in the road or a natural gravel area beside the road can be utilized with little or no preparation. Normally, however, a certain amount of grading followed with gravel or blacktop surfacing is required. The cost of preparing container sites can vary greatly. Average costs reported for three county systems are: Clark County, Arkansas—$67 per site; Wayne County, Ohio—$100 per site; and Chilton County, Alabama—$221.43 per site. These figures are relatively low since all sites do not require extensive work. Clark County, Arkansas, found that costs for those sites requiring work averaged from $300 to $400 per site.

There are several major advantages to bulk bin collection systems. The first is that a collection system is provided where usually none had existed before. Promiscuous dumping and use of community dumps are generally reduced. Public acceptability is usually high. The sites can be located close to the users, and population and waste-generation changes can be easily adapted to by changing the number and locations of the containers. A centralized sanitary landfill that incorporates economies of scale can be used. Servicing of commercial and industrial establishments and recreational areas can be easily done. Not the least advantage is that the costs of this kind of system, once established, can be predicted to a reliable degree.

As with any system, there are also disadvantages. The initial capital investment cost may be quite high. In 1975, prices for front loaders for rural use started at approximately $40,000 and for smaller containers at $200 each. (There are models of front loaders that sell for less, but they are not as suitable for the long daily mileages on unimproved roads that rural collection entails.) Another possible problem is that initiation of a new program may cause existing collection systems, whether private or municipal, to immediately decrease service in the area. Also, on some models of the small containers, the lids are too heavy or are difficult for children or small adults to open. As a result lids may be left open or wastes may be placed outside of the container. With the larger roll-off type containers, lids are usually not provided or are left open at the container site, allowing rainwater and flies to enter and the blowing of litter. At a minimum the containers need to be covered for hauling to the disposal site.

The system can be financed by user charges but only with difficulty. As with any unattended site, vandalism may occur and unsanitary conditions may develop unless the sites are properly maintained. Users of the system must carry their own waste to the containers, which may be a hardship for those without means of transportation. To work well, this kind of service must supply a substantial number of containers at accessible sites. The amount of waste picked up at each site may be unpredictable and cause scheduling problems, at least until new sites or more containers are supplied. Finally, if this kind of rural service is used near municipalities, the containers may be used by town residents if there is inadequate town service.

Mailbox System

In this house-to-house collection system, a collection vehicle travels rural postal delivery routes collecting waste that has been placed next to mailboxes.

This system assumes: (1) if a mail truck can travel a route, a collection vehicle can travel the same route; (2) over the years, the postal system has probably developed the most efficient routes for traveling the region; (3) since all mailboxes on a rural route are required to be accessible to a driver and on the same side of the road, containers will have to be picked up from only one side of the road. For households that do not have mailboxes on the postal routes, the resident and collection agency must agree on a mutually acceptable collection site. A house-to-house system such as the mailbox requires that collection days and times be designated so that residents know when to set out their waste. Recently the mailbox system has become very popular in Alabama, where 67 percent of the unincorporated population is now served by this method in comparison to 23 percent served by bulk containers.

The advantages to this type of system are that it collects the largest percentage of generated household waste of any system, it permits a high level of scheduled service to the rural resident and business establishments, and it provides a system for which user charges can be established.

The mailbox system does have some disadvantages in that homeowners must cooperate in setting out containers on the roadside and following service schedules. Litter problems may occur if bags are torn or if containers are upset along the road. Also, the system may be time consuming and costly to provide in isolated areas.

In considering the use of a house-to-house system for rural solid waste collection, numerous factors must be evaluated in terms of the funds available, such as frequency of collection, type of storage container, kind and size of equipment, and crew size. Most critical is the expected level of participation by residents.

CONCLUSIONS

Two of the four methods of rural waste management rely heavily on the residents themselves, since they must either dispose of the waste on their own property or haul it to a sanitary landfill.

If a bulk storage container system or house-to-house system is proposed for a given rural area, a thorough investigation must be undertaken to determine what the population is willing to support. In order to rationally select between system alternatives, there must be an understanding of the level of service desired as well as the cost for each system.

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Manpower Management and Labor Relations

In any service or industry that is as labor-intensive as solid waste management, a key to productivity is management's ability to lead and to work with employees. Yet many municipal departments in charge of solid waste management are facing problems such as high turnover rates and changing attitudes toward manual work which all too frequently produce a negative attitude on the part of management toward labor in general. Often it is not recognized that many labor problems are rooted in management's inability or lack of desire to manage in a fashion appropriate to current conditions. Moreover, labor is often overlooked as a powerful means for increasing its own productivity. Indeed, public and private solid waste systems have found that it pays to overcome the typical management view of labor as an inevitable source of productivity problems which must be dealt with on an adversary basis at the bargaining table.

Management must first recognize the problems experienced by workers in solid waste systems. Many of them have little education, are from racial or ethnic minorities, and are defensive towards the public since they feel their jobs carry low status. These workers may have entered this field of employment as a last resort. Job satisfaction is often low since most tasks are highly repetitive and routinized. Opportunities for advancement are few because job stratification makes it difficult to provide nonmonetary incentives for increased productivity. Therefore, productivity increases are often dependent on management's efforts to improve morale.

Some of the areas management should examine in assessing its approach to labor relations are incentive systems, crew scheduling, training, opportunities for advancement, safety, and the effects of unionization.

INCENTIVE SYSTEMS

In many communities, incentive systems have increased productivity in solid waste collection while increasing employee morale. The potential for providing effective incentives should be considered for each of the following basic workload systems: (1) the flat 8-hour day, (2) a task incentive system in which a set task is assigned to each collection crew or group of crews and, when the task is completed, the crews are permitted to go home, and (3) a monetary incentive system in which each crew or group of crews has a standard task and is paid an extra amount for any work completed beyond that task.

The flat 8-hour day requires that all crew members remain on the job until their 8 hours are up. Conversely, if they do not finish the assigned work in 8 hours and must stay longer to complete it, they receive overtime pay. The result is that there is no real incentive to "hustle" on the routes.

The task system allows the men to set their own work speed, skip breaks and lunch, and go home early when their routes are completed, provided that no crew has fallen behind during the day due to breakdowns or other unusual delays. In the event of such delays, the first crews to finish are asked to pitch in and help.

When the task is assigned to a group of truck crews (typically all trucks under one foreman), no crew is permitted to go home until the entire task is completed or "covered." This combined task system is often referred to as the reservoir system since on a given day all crews end up in a central or "reservoir" area. With the reservoir system, all crews work a similar number of hours, and peer pressure to set a good pace increases productivity.

The advantage of task incentive systems is that they encourage crews to work faster, thereby increasing productivity. Also, task systems tend to result in a more satisfied work force as long as the task is perceived as a reasonable day's work. A major disadvantage of the task system is that, by working fast to complete the route, there is the potential for a reduction in the quality of service. Additional supervision may be required to ensure that each house receives service and that the solid waste and cans are handled properly. Task systems may also increase the probability of unsafe working practices and fatigue which could result in an increased injury rate. Another consideration is that unions have been reluctant to accept the task system provision in their contracts because it conflicts with opportunities for overtime pay.

There are several methods of providing monetary incentives. One is to give additional pay to crews which, having finished their own tasks, assist other crews which have fallen behind their normal pace because of breakdowns, absenteeism, or other problems. Additional pay may be given also for increased productivity, decreased overtime, or decreased costs. In a private firm a profit-sharing system might be instituted whereby the crews are paid a part of the profits or of increased profits in a specific period. In a public agency, incentive pay could be a share of cost savings.

Another type of monetary incentive is premium pay for difficult tasks. In Fort Worth, where the system changed from backyard to curb service, a premium of 10 cents per stop per week was paid for stops which still required backyard service. Unskilled workers interested in this incentive could request routes with some backyard service and make an additional $15-$20 per week. The effect of this incentive on the system was an additional cost to management which was partially overcome by a premium charge to the backyard customers.

Other incentives include such diverse arrangements as hot breakfasts, which are served by a landfill operator in Milwaukee and help to get his people to work on time, and cash bonuses for crews missing the least pickups and having the cleanest truck, which are used by firms in Washington, D.C.

A number of collection systems have implemented a "piecework" method of operation. A firm in St. Paul pays its crews according to the number of stops serviced. The effect is improved productivity, and the benefits can be passed on to the consumer.

Detroit has successfully combined a monetary incentive with a task incentive. Gains from increased productivity are split between the city and the crews. Those crews with the best performance records receive the largest bonuses. The performance measures used by Detroit and the relative weight of each are:

Paid man-hours per ton (50 percent)
Overtime reductions (20 percent)
Percentage of routes completed (20 percent)
Quality of pickup (10 percent)

Regardless of the workload system used, it is important to have a standard for a fair day's work for each route in terms of number of stops. Usually, all routes should not have the same number of stops since housing density, road widths, street traffic, distance from disposal site, the presence of hills or alleys, and other factors introduce variability among routes. A fair day's work can be determined for each route through time-and-motion studies, and tasks can be negotiated with the union or the workers. In many situations, the drivers and crews know the areas far better than anyone else and they should therefore be participants in any rerouting effort. In addition, if they help "design" the route, they have less basis for complaints about the assignments.

In summary, a flat 8-hour-day system requires careful management to keep productivity high and to maintain quality control. An incentive system should lead to high productivity because of the desire of the crews to finish their tasks quickly. But management must keep the tasks balanced and make sure the work is done properly. Either system can be effective with good management. If cost is the major criterion, a switch to an incentive system may make increases in direct productivity possible. If a high level of service is more important, it may be easier to achieve with a flat 8-hour-day system.

Assignment of Crews and Routes

By more efficient and rational assignment of men to jobs, productivity can be increased and working conditions improved.

Most solid waste managers make an attempt to organize compatible crews who like to work together, and in theory this should lead to higher productivity. A major problem is that absenteeism and turnover make continual reassignment necessary.

One of the simplest suggestions for crew assignment has been to distribute questionnaires to crew members which ask their preferences regarding those persons with whom they would and would not choose to work. The questionnaires are kept confidential and used to make permanent crew assignments. This system can work well in communities where absenteeism and turnover are low, but in other cities it may be difficult to implement. In many instances, crew members play a major role in crew assignments by letting the foreman or supervisor know with whom they prefer to work; permanent work assignments are then determined based on this information. There is no easy solution, however, and the best answer appears to be an astute supervisor who has the ability to recognize traits, personality characteristics, and the ability of people to work together, and to cajole permanent crews into accepting replacements or new personnel.

The assignment of crews to particular routes can also be complicated. Managers can often identify the most efficient crews and they may wish to use this information to increase productivity. Research has shown that in an incentive system it is best to assign equal tasks to all crews. With a fixed 8-hour day, however, unbalanced routes may result in optimum productivity. Assigning higher productivity crews to routes in areas with higher concentrations of waste and lower productivity crews to routes with more travel time between stops may result in greater tonnage collected per day.

Training

Training is important in establishing good labor-management relations and in helping the collectors, drivers, equipment operators, mechanics, and other employees to better understand both their jobs and the system. Employee orientation should include introductions to supervisors and managers. Training in basic public relations, work rules, unit operations, safety, and equipment use and care should be scheduled for optimum participation at regular intervals.

Such training sessions may be difficult to schedule and it may be necessary to offer incentives for participation, but when well planned they can help reduce equipment breakdowns, improve relations between the collectors and the community, reduce injury rates, and save money. These sessions also provide a useful forum for the discussion of problems and demonstrate management's interest in the worker.

EPA's Office of Solid Waste Management Programs has developed materials for two major training courses: *Operation Responsible; Training for Safe Refuse Collection* and *Training for Sanitary Landfill Operations* (see bibliography). Many State agencies have also produced similar materials.

Kansas City, Missouri, has provided its employees with the opportunity to study for high school equivalency tests at the city's expense. The city has also conducted extensive in-house training programs on driving skills, safety, and technical aspects of solid waste management. The program has resulted in a definite improvement in employee morale and more efficient operations.

OPPORTUNITIES FOR ADVANCEMENT

Advancement in the form of promotions is slow in solid waste systems because of the relatively few supervisory positions in relation to the total work force. However, it may be advantageous for management to spend time developing a career ladder for employees. Numerous studies of the behavior of unskilled workers have shown that the perception of a career ladder improves performance since the workers do not feel they are in dead-end jobs. Career advancement should not become an automatic process, however, but depend on the qualifications of the employees. In order to develop a successful career ladder, opportunities for further education or training should also be available.

One public system that has achieved some significant success in career advancement is the one in Inglewood, California. Inglewood's system operates on the premise that its solid waste workers should not remain on the job for more than 3 years and actively assists employees in moving out of the system into higher level jobs. This is possible because the community is willing to provide training in various skills for its employees through local community colleges and night schools so that they can eventually obtain "better" jobs as policemen, firemen, accountants, etc.

In general, little has been done to develop career ladders in solid waste management. Most systems utilize other motivating factors, primarily pay raises and improvements in benefits.

SAFETY

Solid waste collection workers have an injury frequency that is the highest of any industry recorded by the Bureau of Labor Statistics, and an injury severity rate (total days lost due to injury per fixed number of man-hours worked) that is among the top 10. This very serious injury problem represents not only human costs but also high financial costs, both direct and indirect, and creates difficulties in labor relations. National Safety Council data indicate that the problem has been worsening over the past several years.

This poor safety record shows evidence of neglect, apathy, and poor management by both municipal and private collection systems. Attempts have been made to improve collection safety through training and changes in equipment design and standards development. Such safety devices as gloves, safety glasses, respirators, and special footwear can contribute significantly to the health and safety of collection employees. The use of plastic leakproof tubs for manual carryout collection rather than such primitive containers as pieces of burlap will help to minimize physical contact between the collector and the wastes. The prohibition of practices such as scavenging will also help to avoid injuries.

Dramatic cost savings can be realized by implementing safety programs. The city of Milwaukee instituted *Operation Responsible*, a training program developed by EPA, in their solid waste operation and reduced their injury frequency rate by 32 percent from 1972 to 1973. This resulted in savings of $46,655 in salaries and wages. In 1974, however, Milwaukee put less emphasis on the safety training program and injuries increased again. The city's experience confirms the belief that safety training must be a continuous program.

EPA has developed and is currently field testing a recording system that can be used to collect reliable and useful data on injuries in the solid waste field. The Injury Reporting Information System (IRIS) has been in use in 11 public and 5 private collection systems for the past year.

Preliminary findings indicate that in most of the systems studied, management, while aware of the general seriousness of the injury problem, was not aware of the specific details or costs and felt that the experience of their organization was typical and inherent in this type of work. This view was not borne out by the data collected. Even allowing for inconsistencies and unreliability, it was clear that there are very wide variations in injury experience from one organization to another, both in frequency and type of injuries. Finally, it was found that presenting the management of an organization with data on its injury patterns and costs as compared to those of other organizations appeared to motivate action which would reduce injury rates. These results, and experiences such as that of Milwaukee, indicate that the injury rate can be reduced and is not inherent in this type of work.

UNIONIZATION AND LABOR-MANAGEMENT RELATIONS

Many public employees are demanding what they consider to be their legitimate rights in a free, democratic society: the right to organize; the right to bargain collectively; the right to enter into a binding agreement reached through meaningful, good-faith negotiations. They demand to be heard when they have grievances. Refusing to recognize legitimate rights of public employees to organize has been a common failure in many public officials.

Strikes by sanitation workers have shown that State laws prohibiting strikes are not effective. Public employees are willing to strike (or to use various devices as substitutes for the direct strike) to gain bargaining rights—in violation of the law, if necessary. However, thousands of agreements negotiated without strikes between government agencies and their employees furnish proof that sound labor-management relations can exist within a framework of unionism.

Local governments should provide for receiving, evaluating, and taking appropriate action on employee complaints and suggestions. Complaints should be handled through established grievance procedures. If no formal grievance and appeals procedures exist, frustrations will grow when an airing of views might have led to satisfactory solutions. Both agency management and employees must understand and have confidence in the procedures.

When there is a collapse in labor-management negotiations, the causes are related to the experience and approach of each of the two sides and will vary from case to case, but they may well include:

1. Management is unprepared to "meet, confer, or bargain" with their employees: management representatives have no position to bargain from, or goal to bargain toward; they have no expertise in the bargaining process; their management role is unclear.
2. There is no established machinery for working out the resolution of impasses.
3. The variety of procedures available for resolving labor-management problems are not well recognized.

CONCLUSIONS

Management has open to it a number of ways of developing better labor relations, including incentive systems, safety measures, training and career opportunities, and clear acceptance of the employees' bargaining rights. Such improvements can not only help avoid those critical total collapses that have occurred in some cities but also promote good morale, efficiency, and lower costs in the long run.

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TRANSFER STATIONS AND HAULING TO DISPOSAL SITES

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In many areas of the country, sanitary landfills are distant from urban areas because suitable land is not available nearby. The result is that many man-hours can be spent in hauling solid waste from the collection zone to the disposal area. This situation can be alleviated by using a transfer station.

A transfer station is a facility where the solid waste from several relatively small vehicles is placed into one large vehicle before being hauled to the disposal site. The small vehicles can be private automobiles, pickup trucks, or, more commonly, collection vehicles. The large vehicles can be barges, railcars, or trucks.

Although a transfer operation offers potential savings, it requires an extra materials-handling step and the construction of a transfer facility. The associated costs must be recovered or money will be lost in the transfer operation. The costs that are incurred are as follows:

1. The capital expenditures for land, structures, and equipment
2. The costs for labor, utilities, maintenance, operation, and overhead at the transfer plants
3. The costs for labor, operation, maintenance, and overhead incurred in the bulk hauling to the disposal site

Costs are saved with the utilization of a transfer operation because:

1. The nonproductive time of collectors is reduced since they no longer ride to and from the disposal site; it may be possible to reduce the number of collection crews needed because of increased productive collection time.
2. Any reduction in mileage traveled by the collection trucks results in a savings in operating costs.
3. The maintenance requirements for collection trucks can be reduced when these vehicles are no longer required to drive into the landfill site. Much of the damage to suspensions, drive trains, and tires occurs at landfills.
4. The capital cost of collection equipment may be reduced; since the trucks will be traveling only on improved roads, lighter duty, less expensive models can be used.

ALTERNATIVES

Barging

New York City and Seattle are among the few cities now using barges to haul waste to disposal sites. Barge haul does not seem to have much potential for development in the near future except in very specialized applications.

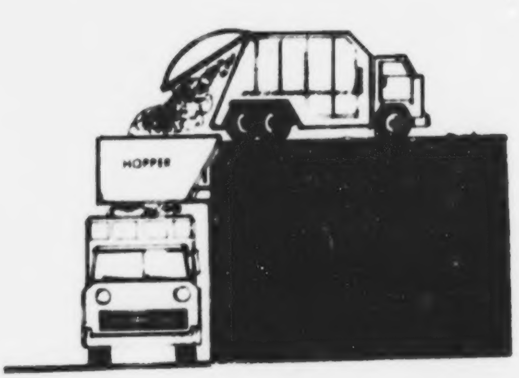
Rail Haul

Rail haul has generated considerable interest in the past several years, but to date no city has solved all the political problems associated with the concept. Rail haul does, however, have the potential to become a major factor in the national solid waste management system. Most of the proposed rail haul projects designate strip mines as the disposal site. When this is the case, two environmental problems can be solved: the proper disposal of waste materials and the reclamation of the strip-mined areas.

Truck Transport

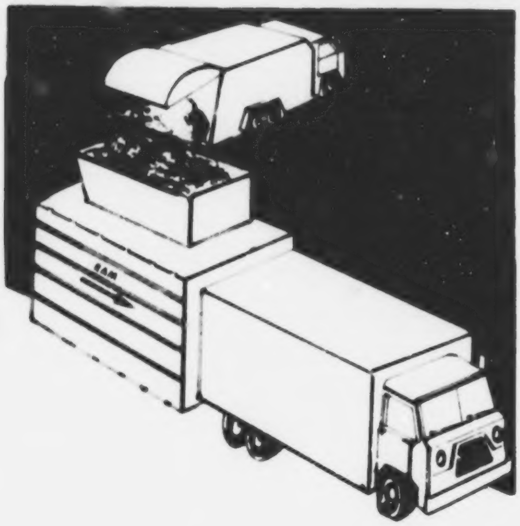
The popularity of truck transfer systems has led to the development of equipment specifically suited to this purpose. Early transfer station operations relied completely on equipment built by various manufacturers to specifications of the operating authority. In the 1960s, solid waste equipment manufacturers developed specialized processing and hauling equipment. At the present time those interested in a truck transfer operation have the option of either designing their own system and writing specifications for desired equipment or buying specialized equipment from the manufacturers and designing the system around it.

Two basic types of transfer systems have developed as a result of these options. The first is the direct-dump system where a collection truck dumps by gravity into a large open-top trailer. The trailer is located under a funnel-shaped hopper to prevent spillage, and a backhoe is usually used to compact and distribute the load after it has been placed in the trailer. A variation of this system utilizes a dumping pit where a crawler tractor crushes and compacts the waste before pushing it into the trailer via the hopper. Because of the densities achieved with the crawler tractors, a backhoe is usually required for load distribution only. The compaction pit system is used primarily in high-volume transfer stations because of the expense of incorporating the extra equipment, whereas the basic direct-dump system has been used in both small and large installations. All direct-dump systems are characterized by the fact that open-top trailers are used and the equipment employed is usually not specially predesigned for solid waste transfer. Some type of cable system is usually employed to pull the loads out of the rear of the trailer at the disposal site.



The second basic transfer system utilizes hydraulic pressure to achieve horizontal compaction of the waste within the trailer. Two methods have been used to achieve compaction. Both are characterized by the use of enclosed reinforced-steel trailers specifically manufactured for solid waste transfer. The first compaction method is partially a direct-dump operation in that waste is dumped directly into the trailer, near the front. A hydraulic-powered bulkhead traverses the length of the trailer and compacts the waste against the rear doors. The entire compaction process is self-contained within the trailer body. At the disposal site, the bulkhead pushes the load out through the rear doors.

The second compaction method requires the use of a stationary compactor. The transfer vehicle is backed up and securely fastened to the compactor. Waste is fed by gravity into the compactor chamber from an overhead hopper. The compaction ram forces the waste forward into the trailer through the rear in horizontal reciprocating cycles. This trailer is also equipped with a hydraulic-powered bulkhead which traverses



the length of the trailer for unloading at the disposal site.

The maximum legal payload for any transfer system is governed by State regulations for gross weight, axle weight, as well as limitations on length, width, and height of the trailers and/or rig. To determine the optimum configuration, the designer must work backward from these limitations. Direct-dump systems with limited compaction require large-volume trailers to reach maximum payloads. Compaction systems need smaller volumes because of the higher densities, but structural reinforcement of these trailers increases the tare weight and lowers the payload. The maximum legal payload can vary from 15 to 25 tons depending on local limitations and options chosen by the designer.

COSTS

Barging

There are no representative cost figures available on barging.

Rail Haul

Because of the lack of any sustained operating experience in rail hauling solid waste, it is impossible to provide accurate cost figures. The city of Philadelphia, however, now has under consideration proposals for rail hauling 1,000 tons of solid waste per day, and the estimated cost is $13 per ton. Under this plan, the wastes would be placed unprocessed in large containers which would be loaded into flatcars for shipment.

A project that includes rail hauling 8,000 tons of unprocessed solid waste per day is being planned in St. Louis. The waste will be delivered to five transfer stations in the city, compacted into 100-cubic-yard containers, and loaded onto flatcars. The waste will be rail hauled an average of 25 miles to a powerplant for processing. Ferrous metal will be recovered magnetically, and the combustible waste will be used as supplemental fuel in a coal-fired utility boiler.

Truck Transport

For truck transfer operations, the best method of reporting the cost is to use two categories. The first category is the cost of owning and operating the transfer facility. Data collected between 1968 and 1971 show costs ranged from $1.25 to $2.25 per ton. The second category is the haul costs. These costs ranged from $1.50 to $2.50 per ton. From the facilities that do not report costs in these categories, total costs ranging from $2.25 to $4.50 per ton were reported.

In general, anyone considering a transfer operation must determine if the savings will exceed the costs. The primary variable is the distance to the disposal site. Attempting to apply a rule of thumb (such as "A 10-mile haul distance justifies transfer") to this determination is unrealistic and mere guesswork unless a study is made of local conditions. A decisive distance in one area may be totally insignificant in another. Factors such as wage rates, type of access roads, collection truck capacity, and size of collection crews (one-man, two-man, etc.) can change the break-even distance considerably.

Although distance to the disposal site is important in comparing direct haul with transfer and haul, a more realistic criterion is the time necessary to travel the distance, since the major item in total haul cost is labor, which is directly related to time and not distance. Variables such as routes taken, traffic conditions, and speed limits could result in a time of 15 minutes to cover 10 miles in one area and an hour in another area.

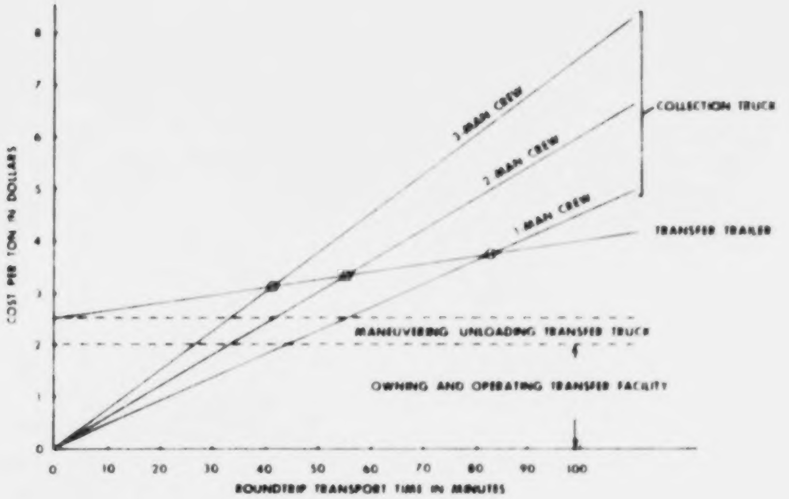


FIGURE 8. This chart, based on hypothetical data, illustrates a typical method for evaluating costs of transporting waste to the disposal site. For the transfer rig, the haul cost is imposed on the cost of transfer operations. A cost for transfer of $2.50 per ton has been assumed. Ultimately the curve for the transfer rig plus the transfer station will intercept the steeper curve for the collection packer truck. The point of interception, when projected downward, will show the round-trip time at which a transfer operation is justified. The data used to derive this graph is presented below, solely for the purpose of demonstrating the method. (Source: GRECO, J. R. Transfer station feasibility is measured against direct haul. *Solid Wastes Management*, 17(4):13, Apr. 1974.)

Transportation costs per vehicle	Direct haul	Transfer
Time-based costs per year		
Vehicle amortization*	$5,260	$9,468
Driver's salary, fringe benefits†	10,625	12,500
Collector's salary, fringe benefits†	9,375	0
Vehicle insurance, licenses, taxes	1,500	2,500
Subtotal	26,760	24,468
Subtotal per minute‡	$0.214	$0.196
Mileage-based costs per mile		
Fuel,§ oil, tires	0.080	0.150
Maintenance and repair	0.050	0.050
Subtotal	0.130	0.200
Subtotal per minute¶	0.087	0.107
Total per minute	0.301	0.303
Total per ton per minute	0.060	0.015
Estimated cost per ton for owning and operating transfer facility	0	2.00
Estimated cost per ton for maneuvering and unloading transfer vehicle	0	0.50

* Diesel compactor truck ($25,000) with a 5-ton payload capacity and diesel tractor trailer ($45,000) with 20-ton payload capacity amortized over 6 years at 8 percent per annum.

† Fringe benefits approximated as 25 percent of salaries (collection truck driver, $8,500; collector, $7,500; transfer trailer driver, $10,000).

‡ Assumed 5-day workweek, 8-hour workday.

§ Fuel costs dependent upon price (e.g., 30 cents per gallon) and consumption (e.g., 6 miles per gallon).

¶ Round-trip transport, 40 miles; round-trip transport time, 60 minutes for collection truck, 75 minutes for transfer trailer.

For these reasons, the usual unit of comparison, the cost per ton per mile, should be replaced by the more realistic unit of cost per ton per minute when making transfer station calculations (Figure 8). In general, a larger vehicle has a greater payload and a lower cost per ton minute (or mile). Thus the 20-ton transfer rig has a flatter haul cost curve than does a 5-ton collection packer truck, but the haul cost for the transfer rig must be superimposed on the cost of the transfer station.

ADVANTAGES AND DISADVANTAGES OF TRANSFER STATIONS

Even though a transfer operation requires an extra materials-handling step and the construction of a facility, its use may reduce the system's total costs by reducing nonproductive use of collection labor and equipment.

In a system using a transfer station, the opening or closing of a particular disposal site will not affect the collection routes. A transfer system makes the collection operation independent of the disposal facility.

The major disadvantage of setting up a transfer station is the problem of public opposition, which is common to almost all solid waste management facilities. While many people will recognize the need for a facility, very few will allow it to be built near their homes.

OTHER CONSIDERATIONS

The economic justification of a transfer system requires a reduction in the number of collection crews needed in an established collection system. This will bring about a surplus of men and equipment within the operating agency, as well as a need to redistribute the workload among the remaining crews.

CONCLUSIONS

Transfer systems offer an economical alternative to direct haul of solid waste by the collection crew to a distant disposal site. No rule of thumb exists to determine when to use a transfer system. Each case should be evaluated individually on the basis of distances to disposal sites, local labor costs, and other factors.

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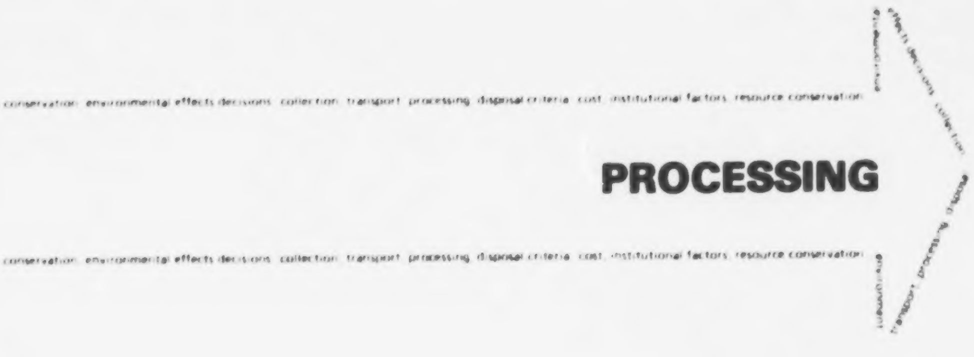
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PROCESSING

Baling

Baling is a method of reducing the volume of solid waste. It has the potential to achieve cost savings when transfer and long haul are necessary prior to disposal and when land disposal space is at a premium. It also has an added benefit in that baling makes the waste potentially easier to handle and transport. The decision to be made is how well baling and the operation of the balefill compete with nonbaling processes (discussed in following chapters) and conventional landfilling. The comparison should be made on an economic and environmental basis for the particular community. The different forms of baling must be compared with each other as well.

ALTERNATIVES

There are, at present, three main types of solid waste balers. One type, developed from the metal scrap baler, achieves densities which are high enough to eliminate the need for baling wire. Raw solid waste is baled in a multistage baler without any preprocessing. This is a batch-feed operation; it is multistage because two or more platens compress the material. This type of unit has been evaluated in St. Paul, Minnesota.

The second type, which was developed from the hay baler, is a horizontal, continuous push-through type of solid waste baler. Use of this system requires preshredding in order to obtain a homogeneous material for the continuous feed hopper, thereby minimizing bridging, or blockage, in the hopper. The bales are also secured by tie wires to retain their compaction.

A third type of solid waste baler was developed from the baler used with corrugated cartons at supermarkets and other commercial establishments. This system requires no preprocessing though tie wires are required due to the lower density obtained. Two manufacturers have sold most of the solid waste balers now being used; others are now entering this market, however.

COST

Because of the relative newness of solid waste baling technology, firm cost figures are very difficult to establish. For the two baling projects in which EPA has been involved, costs per ton were $6.38 and $9.20, respectively (Table 29). In all fairness to the baling concept, it should be noted that high costs have very often been attributable to

TABLE 29

ECONOMICS FOR THE TWO EPA BALING PROJECTS, 1975

Item	San Diego	St. Paul
Capacity (tons per day)	78*	425†
Capital costs	$1.50/ton‡	Not available
Operating costs per ton		
Baling	5.93§	4.10¶
Hauling to balefill	1.42**	1.29††
Disposal	0.35**	0.99††
Total costs per ton	$9.20	$6.38

* Design capacity of 150 TPD or 19,500 tons per year was not achieved because this was a pilot plant. During the evaluation period 7,523 tons were processed or 78 TPD.

† Design capacity of 50 tons per hour was not achieved since this was a demonstration plant. During this evaluation 155,614 tons were processed or 425 TPD, a utilization rate of 80 percent.

‡ Based on a capital cost of $347,151 including engineering and equipment but not site costs. Amortized for 20 years at 6 percent.

§ Includes labor, materials, supplies, equipment maintenance, rental, and utilities.

¶ Includes labor, utilities, equipment maintenance, supplies, equipment rental, taxes and fringes, and depreciation.

** Includes labor and equipment rental.

†† Includes labor, equipment maintenance, supplies, equipment rental, taxes and fringes, and depreciation.

the pioneering nature of the projects; that is, because of stoppages to make adjustments and refinements, the balers have not been running at full capacity for sustained periods of time. Consequently, costs are spread over a reduced tonnage. In a demonstration project in San Diego using the shredding/baling process, the capital and operating costs for processing 78 tons per day (6 hours' production time) were $9.20 per ton exclusive of land costs. Operating costs for the St. Paul evaluation project were $6.38 per ton for processing 425 tons per day (15 hours' production time). No capital costs were available for this project, but the facility is identical to the plant installed in Cobb County, Georgia, which is discussed below.

Information from a telephone survey indicates that solid waste baling facilities are planned for over 12 locations across the United States. Projected economics are available for four of these locations that are or will be operational by 1976 (Table 30). One facility in operation since January 1975 is the $2.4 million baler in Cobb County, which processes 300 tons per day (TPD). Projected capital and operating costs for this facility are $6.20 per ton excluding land. In April 1975, Chadron, Nebraska, dedicated their $220,000 baler. This facility is processing 11-15 TPD and serves the needs of this city's 6,000 population, but with a design capacity of 20 tons per hour, it is capable of handling additional waste from surrounding communities. The operating costs over a 2-month period are $4.27 per ton, which excludes equipment depreciation but includes disposal at the adjacent balefill. Omaha, Nebraska, will be implementing a $4.5 million three-unit baler operation in late 1975, processing 400 TPD. Two of these balers will have a smaller capacity than the third and will be used for backup. Capital and operating costs are projected to be $6.70 per ton, excluding land. The city of Atlanta is constructing a $2.5 million shredding/baling plant which will be processing 500 TPD.

TABLE 30

PROJECTED ECONOMICS FOR OTHER MUNICIPAL SOLID WASTE BALERS, 1975[*]

Item	Cobb County, Ga.	Chadron, Neb.	Omaha	Atlanta
Design capacity (tons)	300/day	20/hr	400/day	500/day
Capital costs per ton[†]	$2.00	--	$3.70	$1.65
Operating costs per ton[‡]	4.20	$4.27	3.00	4.25
Total costs per ton	$6.20	—	$6.70	$5.90

[*] Personal communications to S. J. Hitte, EPA, April-June 1975.

[†] Includes engineering, building, equipment, and construction but not site costs. Amortized for 20 years at 6 percent.

[‡] Includes labor, utilities, equipment maintenance, and miscellaneous expenses. Does not include hauling or disposal costs.

Projected capital and operating costs are $5.90 per ton excluding land. All of these projected costs were based on 1975 figures and, except in the case of Chadron, do not include transfer and disposal costs.

ADVANTAGES

- Baling nearly doubles the life of the land disposal site and therefore reduces the number of times the city government must go through the politically difficult process of acquiring a new disposal site. Densities vary from 1,000 to more than 1,700 pounds per cubic yard, depending on the type of baler used.
- Balers can handle most types of wastes.
- Cost is comparable to costs of other forms of solid waste processing; bulk reduction makes long hauls more economical.
- Bales are easier to handle and transport than unprocessed waste; they are therefore more convenient for operations such as rail hauling.
- Baling should permit more immediate use of the disposal site upon completion since minimal settling is anticipated.
- In shredding baling operations, ferrous metal can be recovered for recycling via magnetic separation after shredding. Also corrugated containers and white goods can be handpicked and baled separately and sold.

DISADVANTAGES

- Baling involves a greater initial investment than a conventional transfer station handling the same tonnage.
- Baling precludes resource recovery once the bale is formed.
- There are gaps in knowledge about the economics of baling and effects of baling on decomposition in landfills, gas and leachate formation, and settling.

OTHER CONSIDERATIONS

Other issues to be examined in deciding whether or not to bale are:

Utilization Rate

The results of the EPA evaluation in St. Paul indicated that a baler operating at a utilization rate of 80 percent or greater was economically competitive with other forms of solid waste processing such as shredding or small-scale incineration. On a throughput tonnage basis this translated to 425 TPD for the St. Paul baler. If a utilization rate of 100 percent (510 TPD) was maintained, that is, if no breakdowns occurred within the baler or the support equipment, then the costs would be expected to improve on the order of 30 percent. Conversely, if lower utilization rates—between 50 and 80 percent (255 to 425 TPD)—were maintained, then the economics might become noncompetitive. Economics, though, should not always be the determining factor; the environmental effects of baling and other solid waste processing systems must also be weighed.

Type of Waste

Grass, yard clippings, and leaves cannot be included in concentrations greater than 50 percent by weight, or the bales in some operations will not retain their integrity. Under normal operating conditions, such material can be dispersed at the baler plant so that this is not a problem.

Environmental Quality of Landfill Site

The balefill in St. Paul was monitored for leachate generation, temperature, gas, and settlement for 14 months as a part of the evaluation project. The results showed that leachate was generated in sufficient quantities to require treatment, though the high-density bales hindered leachate flow for the first 8 months. These results disprove the theory that baling prevents leachate production. As expected, the temperatures in the bales fluctuated according to the ambient air temperature. The density of the solid waste caused initial intense decomposition due to the lack of oxygen and high moisture content; this resulted in high initial bale temperatures. Gas analysis showed the usual trends: carbon dioxide and methane levels increased with time, while oxygen decreased. As expected, the bales within the balefill remained basically stable over the 14 months; long-term monitoring will be necessary to determine the extent of settling over time.

CONCLUSIONS

EPA recommends that baling of solid waste be considered by cities generating a sufficient volume of waste (currently defined as those cities generating more than 400 tons per day or populated by 250,000 people or more), especially if close-in land for disposal sites is unavailable and long hauls are inevitable. Cities with less than this minimum tonnage or with a smaller population should examine the prospects of a joint venture with neighboring communities before abandoning the baling concept. It should be noted, however, that baling precludes any subsequent resource recovery process. Recovery must be accomplished before the baling step is begun, as was done with corrugated containers and white goods in St. Paul.

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Shredding

Shredding reduces the volume of solid waste and turns it into a relatively homogeneous material.* Experience in Europe and, more recently, the United States indicates there are several potential advantages to shredding waste before placing it in a landfill. It was found that shredded waste did not attract vectors, support combustion, have an objectionable odor, or lead to littering—problems often associated with the disposal of solid waste on land. The most attractive feature is the bulk reduction achieved. When compacted in a landfill, shredded waste has fewer voids than unprocessed waste; the density is 25 to 60 percent greater, depending on whether daily cover is required. Shredding of bulky items also facilitates incineration and is a necessary part of many resource recovery systems. Shredding equipment has been used in solid waste management at over 40 U.S. locations, and OSWMP has sponsored several projects and studies concerning the process.

The decisions to be made are whether the total benefits realized by shredding outweigh the cost of such an operation, and whether the environmental effects of a shredded refuse disposal site are acceptable.

Costs

For projects in which EPA has been involved, costs per ton ranging from $8.60 up to $10.60 have been observed. In a demonstration project in Madison, Wisconsin, capital and operating costs through 1974 were reported at $8.60 per ton. This is based on a processing rate of 180 tons per day (TPD) and includes hauling (20 miles round trip) and disposal costs. In a recently concluded demonstration project in Syracuse, New York, 1 year's capital and operating costs were $10.60 per ton including disposal. This facility operates on a single-shift basis (8 hours per day), averaging for a 1-year period a throughput of 284 TPD. It is estimated that this cost could drop around $1 as a result of higher throughput tonnages that are expected as startup problems are resolved.

In some other cities which practice shredding, the reported costs have run lower. De

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* "Shredding" is used here as the generic term for all similar size-reduction processes, including pulverization, milling, hammermilling, grinding, and comminution.

Kalb County, Georgia, has been shredding their waste since April 1973. They have two installations; operating and maintenance costs for their 534-TPD facility was $4.80 per ton, and, for their 400-TPD facility, $4.35 per ton. One of the most recently established operations went on line in June 1974 in Charleston, South Carolina. Capital and operating costs are estimated at $4.10 per ton including hauling (0.5 mile) and disposal. The facility processes 1,000 TPD on a two-shift operation.

EQUIPMENT

There are 11 basic types of size reduction equipment commercially available—crushers, cage disintegrators, shears, shredders, cutters and chippers, rasp mills, drum pulverizers, disk mills, wet pulpers, hammermills, and grinders. The Waste Equipment Manufacturers Institute now designates all of these pieces of equipment under the general term "shredder" with the exception of wet pulpers. To date, wet pulpers, hammermills, and grinders have been used in the United States for the size reduction of municipal solid waste, with the hammermills being the most commonly used.

The only place in the United States that the wet pulper is being used for large-scale municipal operations is a resource recovery plant in Franklin, Ohio, funded partially by an EPA demonstration grant; paper fibers are recovered after the pulping process.

Another type of equipment currently used for size reduction of solid waste is the vertical shaft grinder. This machine uses rolling star-wheels protruding from the rotor circumference which grind the refuse by rolling it between the wheels and the housing sidewalls. The material flows through the machine assisted by gravity.

The most common kind of size reduction equipment used is the hammermill. There are two basic types—the horizontal shaft and the vertical shaft. The horizontal-shaft hammermill is the more common. As the name implies, the rotor or shaft is horizontal and supported at each end. Some manufacturers offer reversible rotor horizontal hammermills to save maintenance costs. The vertical shaft hammermills have the rotor placed in a vertical position with the input material moving parallel to the shaft axis, assisted by gravity.

There are two basic variations of both the vertical and horizontal shaft hammermills: the swing-hammer type and the rigid-hammer type. They are similar except that, in the swing-hammer type, the hammers are pivoted on the rotor, thereby potentially reducing the chances of internal jams or damage to the hammers. The swing-hammer type is the most common in solid waste processing.

Particle Size

The size of the particles produced is quite important to the effectiveness of the step following shredding, whether it is energy recovery, disposal, or a combination. The shredding system must be capable of meeting the particular size requirements. Each of the shredders described has provisions for mechanical particle-size control. Besides these provisions, however, other factors can affect particle size, including wear of components within the shredder, the moisture content of the waste, number of hammers used within the shredder, waste composition, and feed rate (tons per hour).

Motor-Size Requirements

The machine size and the power required for a solid waste shredder are determined by the size and nature of the input material, the processing rate desired (tons per hour), and the output particle size required. The particle-size requirement determines the minimum energy theoretically required. The size and nature of the input material determines the minimum horsepower required to attain an acceptable level of performance without frequent jams or damage to the machine (Table 31). The processing rate, or capacity, determines the physical size of the machine and the total horsepower required.

The total machine horsepower needed is simply the product of capacity (tons per hour) and unit power required (horsepower-hours per ton). For example, if the needed capacity is 50 tons per hour, and the

TABLE 31

CATEGORIES OF SOLID WASTE AND ESTIMATED MINIMUM HORSEPOWER REQUIRED TO SHRED

Category of waste	Composition	Minimum horsepower
Medium	Packer truck wastes, such as paper, cardboard, bottles, cans, garbage, lawn trimmings, small crating, small appliances, small furniture, bicycles, tree trimmings, and occasional auto tires.	200
Bulky	Oversize and bulky items of the above plus stoves, refrigerators, washers, dryers, doors, large furniture, bed springs, mattresses, tree limbs, and truck tires.	500
Heavy	Large and dense materials of above categories plus items such as demolition rubble, logs, stumps, and automobile parts.	1,000
Automobiles		1,500

unit power requirement is 20 horsepower-hours per ton, a 1,000-horsepower motor is indicated.

ADVANTAGES

Reduction in Bulk

Shredding can reduce the volume of wastes significantly; in fact, with bulky wastes, the reduction is around 90 percent. This is obviously an advantage in hauling, handling during any process, and landfilling.

Extends Landfill Life

The results of the various EPA shredder demonstration projects have tended to confirm the positive reports from Europe on landfilling shredded waste. It has been found that, because milled waste is not esthetically insulting, it can often be disposed of on land without daily or intermediate cover where hydrogeological conditions permit; however, careful consideration must be given to the character of the waste material and necessary leachate control. Shredded waste is easily placed and compacted. If there is no need for daily or intermediate cover, and density of the waste has been greatly increased by the shredding and by good compaction, it is easy to see how the life of the landfill can be optimized; in some cases, it can be almost doubled. Shredding thus reduces the need to acquire additional land, as well as reducing the often burdensome problem of locating suitable cover material. It must be recognized, however, that even where regulatory agencies permit landfilling of shredded waste without daily cover, the other engineering and operating principles associated with traditional sanitary landfilling techniques must be followed to ensure that the site does not revert to a dump.

Public Acceptance

To date, public acceptance of shredding facilities has been relatively good compared to acceptance of more conventional solid waste processing or disposal facilities. Shredded waste is far more unobtrusive in appearance than nonprocessed solid waste. Also, there are no air pollutants from combustion or water pollutants from process waters associated with shredding. However, litter, odor, and vector problems can develop if housekeeping is poor.

Relatively Low Cost

The initial investment and operating costs for shredding as compared to other reduction processes are relatively low. The increase over that of conventional sanitary landfilling is relatively small. Calculation of the economics of shredding should include the savings in hauling costs due to the decrease in waste volume and the savings associated with the shredding facility acting as a transfer station between the collection area and the disposal site.

Where favorable market conditions exist or develop, the sale of materials separated from shredded waste can be used to further offset the cost of shredding or to subsidize the solid waste system. Shredding can enhance the marketability of certain fractions of the solid waste stream.

Most Wastes Can Be Shredded

A large portion of the total solid waste load can be shredded. Some wastes, however, cannot be put through the mill because of size or density or because they are hazardous, have high moisture content, or have other qualities that normally call for specialized handling in any system.

Use with Incineration and Recovery of Energy and Materials

It has been found that shredding can be used in conjunction with a number of solid waste treatment processes. For instance, bulky combustible waste can be shredded for incineration. Ordinarily many such items have to bypass the incinerator because they are too large to charge or burn well.

Variations of standard solid waste incinerators, such as the vortex suspension burner or the fluidized bed incinerator, require that waste be shredded for proper feeding and combustion. Other thermal processes, such as pyrolysis or use of solid waste as a powerplant fuel supplement, may necessitate shredding.

Shredding is necessary for many other resource recovery processes in which feed material of uniform size is needed, such as air classification. It also facilitates magnetic separation of ferrous metal.

DISADVANTAGES

Materials Handling Problems

Long-term experience in shredding solid waste is still lacking, but the major problems have been identified and significantly reduced. These problems usually center around the materials handling aspect of feeding the mill and subsequent removal of the shredded material. Jamming of the shredder and uneven feeding can significantly reduce the throughput of the mill, although this has generally been solved on a local basis by simple improvisations. This uneven feeding can result in uneven hammer loading and wear, as well as surges in power. At the other end, unless the shredded material is rapidly removed from the mill, a backup jam may occur.

Experience has taught those responsible for operating shredding facilities to install interlocks that stop the input conveyor when the shredder drive motor overloads. This prevents further feeding of material into the shredder, reduces the load, and gives the shredder an opportunity to "clean out" a potential jam before it develops. The typical design is to have an automatic cutoff which stops the input conveyor, with restart being manual, thereby alerting the operator to the stoppage. Many managers of shredding facilities consider the shredder-motor-conveyor interlock the single most important automatic control in the entire facility.

Component Wear

Another problem that has contributed significantly to overall cost and downtime is component wear, particularly hammer wear. Recent developments such as reversible rotors, improved hammer tipping materials, and easier access to internal components promise to significantly reduce costs. Many of the problems caused by bearing wear have been nearly eliminated through proper lubrication, strict specifications, and minimizing of longitudinal movement or vibration of the rotor.

Fires

Due to the high percentage of flammable materials in municipal solid waste, fires can occur in the shredder. Normally, a fire can be snuffed out by continued feeding of the shredder, but fires associated with jams or stoppages must be extinguished. Manually activated carbon dioxide or water extinguisher systems are available. Additionally, heat-sensitive detectors can be installed at the beginning of the output conveyor. When workers notice a fire in the input conveyor, the shredder and the output conveyor can be immediately stopped to keep from spreading the fire.

Explosions

It is almost inevitable that some potentially explosive materials will enter the facility. The majority of these, such as aerosol cans and nearly empty gas cans, may explode within the shredder with little or no consequence. There are, however, some materials which may cause extensive damage to the facility and, more importantly, cause danger to the workers. Placing the shredder outdoors, special pressure relief devices, and other measures should be explored to minimize potential danger and damage. The manufacturers of shredding equipment should be consulted about such provisions. Attempts should be made to screen input material, where possible, to keep potentially explosive items from entering the shredder.

Dust

Dust and small bits of debris are a constant problem around a solid waste shredder. Two techniques are used to minimize the problem. The simplest is a continuous water spray inside the shredder; this reduces the dust and causes most debris to exit the shredder with the discharge. If wet, shredded waste goes into a landfill, however, the added water may increase the potential for leaching. Also if the waste is to be burned as fuel, wetting will reduce its heating value.

Pneumatic dust collection is the other technique used. Typically, pneumatic collectors are used when waste is shredded for burning in an incinerator or boiler where additional water content is undesirable. The device usually consists of a cyclone placed downstream of the shredder and is more efficient than water sprays.

Spillage of shredded material can be minimized by placing some form of cover, such as a wire mesh, over the output conveyors.

CONCLUSIONS

EPA recommends that cities with a severe shortage of landfill space and/or cover material consider shredding if hydrogeological conditions permit. Local regulatory authorities should be contacted to determine how present regulations would affect landfilling of shredded wastes. Other than cover requirements, all normal sanitary landfilling procedures must be followed in landfilling shredded waste; under certain conditions, consideration must be given to leachate collection and treatment.

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Incineration

Incineration is the controlled burning of solid, liquid, or gaseous wastes. Reductions of 80 to 90 percent of the total volume of municipal solid waste, and 98 to 99 percent, by weight, of the combustible portion are possible through incineration. There are end products of municipal incineration, however, that require further processing or disposal; these include the particulate matter carried by the gas stream, incinerator residue, grate siftings, and process water. Incinerator residue consists of noncombustible materials such as metal and glass, as well as incompletely burned combustible materials. Compaction of this residue results in further volume reduction, so that solid waste processed in an incinerator and then compacted in a landfill may occupy only 4 to 10 percent of its original volume in the storage pit. Recovery of metals and other minerals from the residue would reduce the volume even further.

Bulky burnable wastes (logs, tree stumps, mattresses, large furniture, large signs, demolition lumber, etc.) usually are not processed in a municipal incinerator since they are either too large to load in the combustion chamber, burn too slowly, or contain frame steel of dimension and shape that could foul grate operation or the residue removal systems. A few incinerators include grinding or shredding equipment for reducing bulky items to manageable sizes. In recent years, special incinerators have been designed and constructed to handle some bulky combustible wastes without pretreatment. Other large items, such as washing machines, refrigerators, water heater tanks, stoves, and large auto parts, cannot be handled by incineration. Such materials make up about 20 percent, by volume, of community solid waste at the collection point, and under good compaction in a landfill, can be reduced to approximately half their volume as collected. The volume conservation advantage of incineration plus sanitary landfilling of residue and remaining wastes over landfilling alone can be expected to be 2 to 1. In other words, an incinerator can double the life of a land disposal site.

ALTERNATIVES

The changing technology of thermal processing has resulted in many new processes that are now available as alternatives to incineration. These processes have been developed primarily as energy and/or materials recovery systems rather than strictly for volume reduction, which is the basic purpose of incineration (see chapter on Energy Recovery).

Conventional Incineration

Since 1920, 322 municipal-scale incinerators have been built and 42 modifications have been made to increase the capacity of these facilities. As of May 1972, 193 of these plants were still operating.

Conventional refractory-lined incinerators are usually continuously fed, large rectangular chambers, although inclined rotary kilns have also been used. The amount of air supplied to the combustion chamber is greatly in excess of the amount theoretically required for combustion. The excess air serves as a cooling medium, but it also causes turbulence and entrains large amounts of particulate matter. The air pollution control equipment must be large enough to handle the great volumes of air and particulates. With increasingly stringent air pollution control requirements, it has become very costly to build air pollution control systems for these incinerators. The result has been a substantial decrease in the popularity of the refractory-lined incinerator. The air pollution control systems of the more recently developed waterwall incinerators, which are cooled by water and therefore require less air (and which recover energy in the form of steam), cost almost one-fourth less to build and two-thirds less to operate. (The waterwalls are described in the Energy Recovery chapter).

Small Incinerators

Smaller incinerators with capacities of 5 to 12 tons per day (compared with 50 to 300 tons for most conventional municipal incinerators) are being used in commercial and industrial facilities, as well as approximately 30 communities. Almost any size community will generate enough solid waste to utilize the capacity of one of these incinerators. Frequently more than one unit is installed at the same location to provide backup capacity or to handle the normal waste load. In fact, the waste from any size city could conceivably be handled by this type of incinerator if enough units are available.

The combustion chambers of these incinerators are usually cylindrical, with either a fixed grate or no grate and are almost always batch fed. Combustion air is supplied at a velocity low enough to keep from entraining large quantities of particulate matter in the exhaust gases. The total amount of air supplied is only slightly more than the amount theoretically required for combustion. An afterburner is almost always used in the stack and is frequently the only air pollution control device needed to meet applicable codes. Auxiliary fuel is used for startup, maintenance of uniform furnace temperatures, and the afterburner. Either natural gas or fuel oil can be used.

EPA is in the process of evaluating this type of incinerator. The results of the study, which should be available in late 1975, will include data on the operating characteristics and economics.

COSTS

Conventional Incineration

One of the most recently constructed refractory-lined incinerators is in Washington, D.C., where it is identified as Solid Waste Reduction Center No. 1. The construction costs for this plant were approximately $19 million. Operations began in June 1972. The plant has six 250-ton-per-day furnaces. Normal operations call for five of the six furnaces to be in operation, with the sixth shut down for routine maintenance. The working capacity is approximately 450,000 tons per year.

The operating budget for this facility was $1.6 million in fiscal year 1973. Assuming a 6-percent interest rate and a 20-year life, the total operating cost for this plant is slightly over $7 per ton. The 1974 replacement cost was estimated to be nearly $29 million. Using a 6-percent interest rate and a 20-year life, a facility built in 1974 would process solid waste at a cost of over $10 per ton. These cost estimates assume that the incinerator can operate at 100 percent of the working capacity. If less tonnage is processed, the cost per ton would increase.

Small Incinerators

Very limited data are available on the operating costs of the small incinerators.

Fuel costs, which are a major portion of the operating costs, can be expected to rise, and if natural gas is the auxiliary fuel, the availability of fuel may be a problem in the near future.

One detailed study was conducted in an Oklahoma city using a small incinerator. The results of that study indicate a total cost of over $14 per ton, including fuel costs of approximately $5 per ton. However, this facility was operating at approximately one-half of its rated capacity. Further estimates showed that, if the plant were operated at capacity, the cost would drop to between $7 and $8 per ton.

A cost estimate of $5 to $9 per ton for a small incinerator has been obtained from a Florida city. A breakdown of this estimate is not yet available, but these costs will be studied further during the evaluation project mentioned above.

ADVANTAGES AND DISADVANTAGES

Incineration in General

Advantages:

- Solid waste is reduced in weight and volume, and this extends the useful life of the available land disposal facilities.
- Where waste must be hauled long distances to a landfill, incineration may be economically advantageous if close-in locations can be found for the incinerator.
- Incineration is adaptable to energy recovery processes such as steam generation and to recovery of minerals from the residue.

Disadvantages:

- The process requires large capital expenditures and high operating costs.
- Skilled labor is required to properly operate and maintain the facility.
- Improper operations can result in air, water, and land pollution.
- Residents may object to having an incinerator built in their neighborhood.

Conventional Incinerators, in Relation to Small Incinerators

Advantages:

- Conventional refractory-lined incinerators can more readily process large quantities of solid waste.
- Conventional incinerators do not require auxiliary fuel.
- Because they operate continuously, conventional incinerators are potentially a more reliable source of energy recovery (steam generation).

Disadvantages:

- Only large cities can economically operate conventional incinerators.
- Conventional incinerators produce large quantities of process water that must be treated.
- Conventional incinerators require a much longer construction time than small incinerators, which are package units.

CONCLUSIONS

The use of conventional incinerators is on the decline because of high capital and operating cost as compared to other alternatives, stringent air pollution requirements, and the availability of other processing technologies.

The use of small incinerators is increasing among communities of various sizes. The economics of small incinerators have not yet been fully evaluated, but the total cost per ton appears to be at least equal to that of conventional incineration.

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conservation, environmental effects decisions, collection, transport, processing, disposal criteria, cost, institutional factors, resource conservation,

RESOURCE RECOVERY FROM MIXED WASTES

conservation, environmental effects decisions, collection, transport, processing, disposal criteria, cost, institutional factors, resource conservation,

environmental effects decisions, collection, disposal, processing, transport, environment

Energy Recovery

Mixed municipal solid waste is composed largely of combustible materials. On the basis of weight, more than 75 percent is combustible, but more important from the point of view of disposal is the fact that greater than 90 percent of the volume can be eliminated by means of thermal reduction. Historically, thermal reduction has referred exclusively to incineration carried out mostly in refractory-lined chambers. Recently, however, solid waste disposal technology has found many new ways of thermally treating refuse to utilize its energy value. This includes the development of steam-generating (waterwall) incinerators, pyrolysis technology, and various ways to use refuse as a fuel.

ALTERNATIVES

There are several different technologies presently being evaluated that recover energy from solid waste (Table 32). Although no technology is as yet risk-free, two methods are commonly considered "commercially available." Other, possibly better, technologies are being developed and are projected to become commercially available throughout the 1977 to 1982 period.

Available Technology

The technology that is now commercially available includes (1) the generation of steam (for district heating and cooling or for industrial processing) in a waterwall incinerator fueled solely by unprocessed solid waste and (2) the use of processed (shredded and classified) solid waste as a supplement to pulverized coal in electric utility boilers.

These technologies are defined as commercially available because they have been demonstrated in large-scale facilities and because private industry is offering systems based on them for sale.

Waterwall Incinerators. There are a number of waterwall incinerators in operation in the United States, although the steam produced by only a few has been successfully marketed (Table 33). Waterwall furnaces have almost entirely replaced refractory-lined combustion chambers in current incinerator design. In this type of construction, the furnace walls consist of vertically arranged metal tubes joined side to side with metal braces. Radiant energy from burning solid waste is absorbed by water passing through the tubes. Additional boiler packages, located in the flue, control the conversion of this water to steam of a specified temperature and pressure.

In Europe many municipalities combine waterwall solid-waste-fired units with separate fossil-fuel-fired units in the same facility. Steam from the two separate units is integrated to drive one turbine generator system. One reason this concept is widely used in Europe but has not been used in this country is that many European municipal governments, unlike most American counterparts, are

TABLE 32

LOCATION AND STATUS OF ENERGY RECOVERY SYSTEMS BY TECHNOLOGY TYPE AND ENERGY PRODUCT, 1975

	Energy product				
Technology	Electricity	Steam (other than for generating electricity)	Solid fuel (other than for producing steam or electricity)	Gaseous fuel	Liquid fuel
Waterwall incineration:					
Burning of unprocessed solid waste	—	Braintree, Mass.† Nashville, Tenn.† Saugus, Mass.§	Not applicable	Not applicable	Not applicable
Pulped or shredded solid waste	Hempstead, N.Y.**	Hamilton, Ontario†	Not applicable	Not applicable	Not applicable
Processing for use as supplemental fuel for boilers	St. Louis, Mo.† Ames, Iowa§ Bridgeport, Conn.§ Chicago, Ill.§ Milwaukee, Wis.** Monroe Co., N.Y.** New Britain, Conn.**	—	Palmer Township, Pa.**	Not applicable	Not applicable
Pyrolysis	—	Baltimore, Md.‡	—	South Charleston, W. Va.*†	San Diego, Calif.§
Methane recovery:					
From sanitary landfills	Los Angeles, Calif.*†	—	Not applicable	Los Angeles, Calif.*† Mountain View, Calif.*	—
Controlled digestion	—	—	Not applicable	Pompano Beach, Fla.*	—
Direct combustion gas turbine	Menlo Park, Calif.*‡	Not applicable	Not applicable	Not applicable	Not applicable

*Research or experimental operations.
†System in operation.
‡In shakedown.
§Under construction.
**Construction not yet started, but system has been selected.

TABLE 33

CAPITAL COSTS AND CAPACITY OF WATERWALL INCINERATORS PRODUCING AND SELLING STEAM, IN OPERATION OR UNDER CONSTRUCTION, 1975

Site	Startup date	Total capital cost	Capacity (tons of waste per day)	Capital cost per ton of capacity
Braintree, Mass.	1971	$2,500,000	240	$10,400
Nashville, Tenn.*	1974	18,500,000	720	25,700
Saugus, Mass.	1976	38,200,000	1,200	29,200

*System also distributes chilled water.

responsible not only for solid waste disposal but also for power generation, distribution of steam for district heating, and the operation of electrically powered transportation systems.

Solid Waste as a Supplementary Fuel. Solid waste can be used in solid form as a substitute for conventional fossil fuels in existing or newly designed combustion units. The major markets for solid waste fuel are (1) utility steam-electric boilers, (2) industrial steam and steam-electric boilers, and (3) downtown steam and chilled water distribution.

The prerequisite for entry into these markets is that the boilers must be capable of handling both bottom ash and fly ash. All boilers designed to burn coal have ash-handling equipment. Many coal-burning boilers have been retrofitted to burn oil or gas, but the ash-handling equipment is still operable in most cases.

There are two ways to enter the market: construction of a new boiler or modification of an existing one. It is usually less expensive to modify an existing boiler than to build a new one. The largest and most readily available existing boilers are electric utility boilers. Because most of them are suspension-fired (the fuel burns in midair in a residence time of 1 or 2 seconds), the pieces of solid waste fuel must be reduced in size (by shredding, milling, or pulping) so that they can be burned in the boiler's short residence time.

The shredded-waste fuel system being demonstrated by the city of St. Louis, the Union Electric Company, and EPA in St. Louis shreds mixed municipal wastes, separates combustible from noncombustible material, and burns the combustible portion in an existing coal-fired electric-power-generating boiler. Magnetic metals are extracted from the noncombustible portion and sold to a steelmill. Glass, aluminum, and other nonmagnetic materials can also be extracted for resale when technology and economics permit. The system thus conserves resources and, since 95 percent by volume of the system's throughput is recovered, reduces the community's landfill requirements.

Similar systems are already being implemented in several other communities, even though the concept is still being tested (Table 34). The Union Electric Company has announced a $70 million program to expand the demonstration operation to serve the entire metropolitan St. Louis area. In Ames, Iowa, a prepared solid waste fuel will be used in a municipally owned powerplant. In Chicago, it will be used by the Commonwealth Edison Company.

Investigations are being undertaken of other possibilities for solid fuel prepared from solid waste: as a supplemental fuel in oil-fired boilers, pelletizing for use on grates in stoker-fired boilers, and preparation by a wet-pulping method.

The pulped fuel concept is an extension of the wet-pulping separation technique demonstrated by EPA at Franklin, Ohio, using the Black Clawson Company's system. After pulping and removal of noncombustible materials, the remaining material, with a moisture content of about 50 percent after dewatering, can be used as the primary fuel in boilers that are designed to handle materials with high moisture content, such as wood bark from papermill wastes or sugar cane wastes. The pulped fuel could also be dried further and used as a supplementary fuel in existing boilers burning coal or oil. Recovery of heat energy from pulped waste has not been demonstrated on a large scale; however, tests by the Black Clawson Company have been encouraging enough for the company to promote the system in the waste disposal market.

Technology under Development

Pyrolysis. Pyrolysis systems which convert solid waste into gaseous or liquid fuels are being demonstrated with EPA solid waste demonstration grant support in Baltimore, Maryland, and San Diego County, California, and without Federal support in South Charleston, West Virginia (Table 35). These systems are expected to become fully operational during the 1977 to 1980 period.

Pyrolysis is the thermal decomposition of materials in the absence or near absence of oxygen. The high temperature and the "starved-air" situation cause a breakdown of the materials into three parts: (1) a gas consisting primarily of hydrogen, methane, and carbon monoxide; (2) a liquid fuel that includes organic chemicals such as acetic acid, acetone, and methanol; (3) a char

TABLE 34

CAPITAL COSTS AND CAPACITY OF SYSTEMS PRODUCING PREPARED WASTES AS A SUPPLEMENTAL FUEL FOR USE IN UTILITY BOILERS, 1975

Site	Startup date	Total capital cost (in millions)	Capacity (tons of waste per day)	Capital cost per ton of capacity
Ames, Iowa	1975	$5.5	200	$27,500
Bridgeport, Conn.	1976	32	1,200	26,666
Chicago, Ill	1976	16	1,000	16,000
Milwaukee, Wis.	1977	14*	1,200	11,666
Monroe Co., N.Y	1978	30*	2,000	15,000
New Britain, Conn.	?	30	1,200	25,000
St. Louis, Mo. (expansion of pilot operation)	1977	90	8,000	11,250

*Does not include retrofitting of boilers and storage facilities for the solid waste.

TABLE 35

CAPITAL COSTS AND CAPACITY OF PYROLYSIS UNITS IN OPERATION OR UNDER CONSTRUCTION, 1975

Site	Energy product	Startup date	Total capital cost	Capacity (tons of waste per day)	Capital cost per ton of capacity
Baltimore, Md.*	Steam	1975	$16,000,000	1,000	$16,000
South Charleston, W. Va.	Gaseous fuel	1974	?	200	?
San Diego County, Calif.*	Liquid fuel	1976	9,600,000	200	48,000

*EPA solid waste demonstration projects.

consisting of almost pure carbon, plus any glass, metal, or rock that may have been processed. The design of the individual system determines which of these outputs will be the predominant product.

Pyrolysis is under development by nearly a score of different private and public organizations. The primary motivation is the desire to develop a system that can convert solid waste into a storable; transportable fuel—either liquid or gas.

The Garrett Research and Development Company's "Flash Pyrolysis" system, which will be demonstrated by EPA in San Diego County, California, will produce an oil-like liquid that will be used by the San Diego Gas and Electric Company as a supplemental fuel in an existing oil-fired boiler. The fuel has about 65 percent of the heating value of No. 6 fuel oil on a volumetric basis. In this system, mixed municipal solid waste is coarsely shredded and then separated by an air classifier into a light fraction and a heavy fraction. The light material is dried and reshredded to one-sixteenth of an inch before undergoing pyrolysis at a temperature of 900 F. Liquid fuel is produced at the rate of one barrel per ton of solid waste.

A gaseous fuel is being produced by the Union Carbide "Purox" system that is being tested at a 200-ton-per-day facility in South Charleston, West Virginia. The system is characterized by its slagging vertical shaft furnace, its use of pure oxygen rather than air, and the fact that it does not require shredding. The gas product is a clean-burning fuel comparable to natural gas in combustion characteristics but with 30 percent of the heating value of natural gas. It is essentially free of sulfur compounds and nitrogen oxides and burns at approximately the same temperature as natural gas. This gas can be substituted for natural gas in an existing facility; the only plant modification necessary would be enlargement of the burner nozzle to increase the flow rate.

The new pyrolysis system being operated in Baltimore with EPA demonstration grant support combines a waste-heat boiler with the pyrolysis kiln to produce steam. The plant, designed by Monsanto, uses the boiler to recover the heat value from the pyrolysis gases, which are combusted in an afterburner separate from the kiln. When in full operation, 200,000 pounds of steam per hour will be recovered from processing 1,000 tons of solid waste per day. The steam will be transported by pipeline three-fourths of a mile to an existing steam distribution system that is operated by the local utility.

Methane Recovery. The natural biological decomposition of organic waste creates gas. Under anaerobic conditions, the bacteria associated with the decomposition process will generate methane and carbon dioxide in about equal quantities. Methane is the primary component of natural gas.

Anaerobic digestion takes place naturally in a landfill, and efforts to recover landfill gases as an energy source are underway in several locations. More information on recovery of methane from landfills is presented in the chapter on Sanitary Landfilling.

Methane can also be produced by the controlled digestion of solid waste in a digestion tank. The various components of a controlled digestion system, such as shredders, digestion tanks, and gas-cleansing units, are commercially available. However, to date anaerobic digestion of solid waste has not been demonstrated on a large scale.

A controlled digestion system for methane recovery from solid waste will be demonstrated by the Energy Research and Development Administration in Pompano Beach, Florida. This pilot digestor will handle 50 to 100 tons of solid waste per day.

Direct Generation of Electricity. The direct generation of electricity from solid waste combustion is being explored through a research project funded by EPA. The Combustion Power Company has developed a completely integrated solid waste combustion and power generation system known as the CPU-400. A 100-ton-per-day pilot plant in Menlo Park, California, is currently in the development phase.

In this system, incoming municipal solid waste is shredded and air-classified to remove the noncombustible material, from which metal and glass are recovered. The combustible fraction is transported pneumatically into a pressurized fluid bed combustor. The hot, high-pressure gases from the combustor are cleaned and then passed through a gas turbine that drives a 1,000-kilowatt generator.

Performance problems have caused accelerated deterioration of the turbine blades and have thus slowed the development of this process. The deterioration and other problems must be solved before this approach becomes a technically and economically feasible system for energy recovery.

MARKETING CONSIDERATIONS

The key to marketing energy from solid waste is to produce a form of energy that can be utilized without significant inconvenience to the user. A fuel product should be storable and transportable so that the solid waste facility can be built and operated independently of the fuel market.

Marketability of Fuels Derived from Solid Waste. Fuels derived from municipal solid waste have different physical and chemical properties than conventional fuels and thus have different handling and combustion characteristics. In analyzing the market potential for these fuels, some general factors which must be considered are:

- Quantity of fuel produced: enough of the product must be available to justify any expenses to the user in modifying his facility to accept the new fuel.
- Heating value: the heat value of each fuel must be high enough to minimize the effect of the fuel on the boiler or furnace efficiency. Also the costs of transporting, sorting, and handling the fuel will increase as the heat value decreases since greater tonnages or volumes must be handled to obtain the same amount of energy.
- Reliability: a high degree of reliability of the supply of the fuel will increase its value because the user will not have to maintain standby equipment or fuel.

- Particle size, ash content, and moisture content of shredded fuel: particles must be small enough to permit complete combustion when burned in suspension. Ash content should be kept to a minimum so as to prevent erosion of the fuel firing system and the furnace walls, and reduce problems of handling fly and bottom ash. If the moisture content of the fuel is too high it will reduce the combustion efficiency of the boiler.
- Viscosity, volumetric heating value, chemical stability, and special handling requirements of liquid fuels.
- Heating value and transportability are prime considerations for gaseous fuels. The distance which gaseous fuels can be economically transported is limited by the cost of compressing and pumping the gas.

Anaerobic digestion is the only known process that produces an energy form (methane gas) in large quantities that can be used directly by the consumer for home heating, cooking, and other such purposes. When the gas produced is upgraded to pipeline quality (1,000 Btu per cubic foot), it is easily marketed because it can be injected directly into the local utility pipeline system. All other energy recovery processes require conversion to steam or electricity.

The waste-derived solid and liquid fuels can be transported and can even be stored for brief periods of time (several days to several weeks). However, both fuels require the user to install special storing and firing facilities. In addition, the user must follow special handling procedures to minimize problems of air pollution and corrosion. Waste-derived gaseous fuels are less likely to require special handling or need separate facilities for storage and firing, but those currently being produced (other than methane from anaerobic digestion) cannot economically be compressed for extended storage and shipment. The best of the gaseous fuels cannot be shipped more than 2 miles.

Marketability of Steam or Electricity. Steam and electricity derived from waste can both be used without significant inconvenience to the user, but there are constraints which must be considered. For steam distribution systems these include:

- Proximity to customer: the facility must be located close to the steam market. Generally steam can be transported only about 2 miles; in congested areas, extensive piping may further restrict this distance.
- Value: the price of the steam delivered to customers must be competitive with alternative energy sources.
- Quantity: the amount of steam must be sufficient to serve customers' needs, allowing for peak demand periods. Otherwise, standby provisions must be available.
- Operating schedule: steam generation facility must operate on a schedule consistent with the customers' operating schedules.
- Availability of waste: sufficient waste must be assured to meet steam output commitment.
- Steam quality: temperature and pressure of steam produced must be consistent with optimal performance of steam generating plant and the limits acceptable to the customer.
- Reliability: contingency plans must be available in case solid waste flow is impeded.
- Disposal option: should the facility fail to operate, either technically or economically (e.g., depressed steam market), disposal of solid waste must still be provided for. Condensing units or a backup landfill may be necessary.
- Timing: steam must be available when needed and upon demand. Also, unanticipated delays in construction of the facility may divert potential customers to alternative commitments.

The marketability considerations for solid-waste-to-electricity systems are basically the same as those for steam systems, since steam production is usually the interim step in generating electricity. However, electricity systems are not limited by the need for proximity to the customer or steam quality considerations.

Market Opportunities. Markets for solid-waste-derived fuels are likely to be large utilities or industrial users who could supplement conventional fuels with solid waste fuel. Major industrial operations such as cement plants, steelmills, papermills, etc., and district heating/cooling plants are also potential market outlets. Market opportunities for steam similarly include metropolitan areas with commercial and campus district heating and cooling networks and industrial plants which operate steam-electric powerplants.

The major concern in marketing electricity is that it can be marketed only to the electric utility serving the area because, within that service area, the utility is generally exempt from competition. The only exception to that would be a municipally owned utility, but only a small fraction of the nation's electricity-generating capacity falls in this category.

RESOURCE RECOVERY PLANT COST ESTIMATES

Cost is usually the major factor in decisions about whether to implement large-scale mixed-waste resource recovery plants. Cost considerations are also important in formulating State and Federal policies relating to such implementation. Thus it is important that sound methods of evaluating and comparing cost figures be used.

Unfortunately, very little economic data are available. As of August 1975, no full-scale mixed-waste separation plants were yet in regular operation. In the absence of operating data, cost projections must be based upon preliminary estimates by consulting engineers and system development companies; these estimates are derived from experience with pilot-scale operations and from equipment supplier quotations.

A major problem in projecting costs has been the general lack of comparability among cost estimates. There are two apparent causes for this. First, different cost-accounting methods are employed by various designers, making it difficult to compare cost projections in proposals from companies bidding on the same contract.

Second, most estimates have been site-specific and reflect a wide range of factors which vary from site to site. Capital costs on a 1,000-ton-per-day plant may range from $10 to $35 million, depending on the type of system chosen, land and site preparation costs, and construction costs, including labor, materials, and equipment.

Annual costs, which include amortized capital cost and operating and maintenance costs, may vary from $11 per input ton to $24 per input ton, depending on, among other things, the utilization of capacity, the interest rate on borrowed funds, wage rates, utility rates, fuel prices, local taxes, and residual waste disposal costs.

Selling prices for the recovered products also constitute a great source of uncertainty. They exhibit large variations among geographic regions and have been subject to extreme fluctuations over time. Future negotiable prices for recovered fuels and materials are subject to additional uncertainties due to technical questions about product quality.

Product revenues could range from $4 to $16 per input ton, depending on the types and quality of materials and energy recovered, the current market prices, and the cost of transporting the materials and energy.

Based on these estimates for annual costs and product revenues, the annual net results may range from a profit of $5 per ton to a cost of $20 per ton.

Whether the net cost of a resource recovery system is acceptable depends upon a comparison with the present and projected costs of alternative solid waste management methods.

Even those systems that can be called "commercially available" involve considerable risk. However, as more operating experience is accumulated and as more development work is done, better cost estimates can be made and improved systems will be available. There is also a cost of waiting. Inflation is likely to increase the cost of resource recovery systems, and the remaining capacity of current disposal sites must be considered.

RESOURCE RECOVERY PLANT SUCCESS FACTORS

The decision to build a resource recovery plant must be based on a thorough analysis of local conditions. However, a thorough analysis is costly and time consuming, and decision-makers need to have a rough idea about the feasibility of resource recovery before undertaking such a study. It is possible to make a superficial but meaningful assessment of feasibility by considering a few factors that are basic to the success of a resource recovery system.

Economies of Scale

Resource recovery systems require large quantities of waste delivered for processing at one site in order to achieve economies of scale. For this reason, resource recovery appears feasible only in more densely populated urban and suburban areas within which it would be economical to haul large quantities of waste to a single location. The minimum amount of waste required for economical operation has not been determined, but the consensus of the solid waste engineering community is that 200 to 250 tons per day is the lower limit and that plants in the 500- to 2,000-ton-per-day range are likely to be the most economical. Current activity gives the best indication of practical plant size: of the systems currently being designed, constructed, or operated in the United States (excluding demonstration and test facilities), only three—those at Ames, Iowa (200 tons per day), Braintree, Massachusetts (240 tons), and Nashville, Tennessee (720 tons)—have capacities smaller than 1,000 tons per day.

Markets and Product Revenues

To be economical, resource recovery systems must be able to sell their products, and sell them at a satisfactory price. It is important to consider markets *first* and then select a system to recover the appropriate products.

The decision-maker's first step should be to investigate energy markets. The reason for this is that, in most cases, energy products can contribute more revenue per ton of waste processed than all other materials combined. In addition, landfill requirements can be reduced more by recovering energy (up to 80 or 90 percent of the waste input by volume) than by recovering all other products combined.

Once a market has been identified, the decision-maker can estimate the potential revenues from recovered energy products. This can be done in two steps:

1. Estimate *gross revenue* per ton by converting the value of the prospective customer's current source of energy into dollars per ton of solid waste. The question may be raised, What is the effect on revenues from energy recovery if paper is recycled instead of converted to energy? The recovery of paper products has the potential of significantly reducing revenues by reducing the quantity and quality of combustible material. However, at current and past levels of paper recycling, its effect on energy recovery product revenues would be to reduce them by only about 5 or 10 percent. The effect on any particular system must be considered in a detailed feasibility analysis.

2. Estimate *net revenue* per ton by deducting from gross revenue the amount per ton of the customer's cost of using the product. In addition, the price to the customer may have to be discounted in order to make the product more competitive. Data on these costs and discounts are not available, but for purposes of a preliminary feasibility approximation, a 30-percent reduction in gross revenues is reasonable.

Revenues from materials should also be estimated (Table 36). Steel recovery is proven commercially and is economically attractive in almost all instances where shredding is already being performed. Glass, aluminum, or other nonferrous metals may or may not be recovered, depending on local markets and other economic and technological factors. Technology for recovery of glass and nonferrous metals from municipal solid waste has not yet been fully demonstrated.

It should be noted that transportation costs could greatly reduce the revenue contribution of glass and steel due to their relatively low values. Revenues from nonferrous metals would be less significantly affected.

ADVANTAGES AND DISADVANTAGES OF ENERGY RECOVERY

Advantages

In addition to easing energy shortages, energy recovery offers the following advantages over conventional waste management methods:

- Landfill requirements can be reduced. The present landfill can be used longer, and the task of finding the next landfill site will be less urgent.
- Finding a site for an energy recovery plant may be easier than finding a site for a landfill or conventional incinerator.
- Energy recovery is environmentally preferable because total pollution is reduced when compared to a system that includes incineration for solid waste

TABLE 36

ESTIMATES OF THE POTENTIAL GROSS REVENUES FOR MATERIALS RECOVERED FROM A TON OF MUNICIPAL SOLID WASTE IN A MECHANICAL PROCESSING FACILITY

Product	Percent in total waste input*	Percent recovered	Recovery as percent of total waste input	Estimated gross price per ton†	Approximate potential gross revenue per ton of solid waste
Glass	9.9	70	6.93	$16	$1.10
Ferrous metal	8.2	95	7.80	50	3.90
Aluminum	0.7	60	0.42	300	1.26
Other nonferrous metal	0.3	80	0.24	350	.84
Total	19.1	—	15.39	—	$7.10

*Based on national average composition.

†Excludes costs of transporting to markets. Transport costs could significantly reduce the net revenue from glass and ferrous metal.

disposal and burning fossil fuels for energy.

- Public opinion favors energy recovery. Many communities are opposing new solid waste management ventures unless they include resource recovery. Some communities have even said that they would pay more for resource recovery because of its environmental benefits.
- Energy recovery appears to be more economical than environmentally sound conventional incineration or remote sanitary landfilling.
- The future prospects for favorable economic justification for energy recovery are very good because of the soaring costs of fossil fuels and increasing environmental constraints being placed on other alternatives for solid waste disposal.
- Most energy recovery systems facilitate the recovery of materials for recycling.

Disadvantages and Risks

- Most systems will not accept all types of wastes and will produce some residues. Therefore a sanitary landfill will still be needed as a part of the total system.
- Developmental work is still underway on many of the energy recovery options.
- The municipality will have to market recovered products or hire a private company to do this. This is a new task for most municipalities, requiring special skills and possibly changes in municipal regulations regarding the disposition of "surplus property."
- Specific needs of the energy market may dictate parameters of the system design. This could include type of facility, size, site location, or operating hours.
- Most energy recovery systems require raising large sums of investment capital.

CONCLUSIONS

The recovery of energy from solid waste can create mutual benefits for the community and the purchasers of the energy product. Some benefits may be expressed in dollars; others may not. For example, the community may benefit from lower waste disposal costs, less air pollution, and longer landfill life. At the same time, the energy user can benefit from lower fuel costs, a reliable source of low-sulfur fuel, and an opportunity to provide a community service.

If a community wishes to implement a resource recovery system, it must consider both the markets and the technologies that are available. If the decision must be made now, waterwall incineration or the use of shredded solid waste as a supplementary fuel should be considered, recognizing that there are still economic uncertainties inherent in solid waste fuel systems. If a community has a year or so to make the decision about building a system, it should delay the decision until then because by that time the degree of economic viability of solid waste fuel systems should be much clearer. If the decision-making time is from 2 to 5 years away, oil or gas pyrolysis should also command major emphasis in the community's planning, for these systems should be fully demonstrated during this time. It should be remembered, however, that the time between system selection and actual operation—the time for procurement, design, construction, and shakedown operations—could conceivably be as long as 5 years. This must be considered when determining the lead time available for decision-making.

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Materials Recovery

The decision to be made is whether or not to engage in recovering the various materials in solid waste and to what extent. In this context materials recovery is considered to be any manual or mechanical process in which one or more of the various components in the solid waste stream are separated, concentrated, and sold. The recovery of steel cans and other ferrous metals from the waste stream using a magnet is an example of one type of materials recovery. Materials recovery systems vary in cost, complexity, and risk from the relatively simple process of ferrous metal recovery to systems that extract not only ferrous metals but also glass, paper, and aluminum and other nonferrous metals from the waste stream.

The decision to proceed with such a system is based primarily on costs versus benefits and on anticipated technical feasibility, although there are likely to be other constraining prerequisites for many of these systems.

ALTERNATIVES

There are two basic kinds of materials recovery: precollection and postcollection. Precollection recovery, or recovery before the materials become mixed in a collection vehicle, is discussed in the chapter on Source Separation. This chapter will deal with postcollection materials recovery, that is, recovery of marketable materials from mixed municipal solid waste.

There are three approaches to implementing such a materials recovery system.

Complement to Land Disposal

A growing number of communities are adding shredding and ferrous metal recovery systems to their landfill operations. Shredding may be done to improve landfill operations and reduce landfill volume requirements (see the chapter on Shredding). Shredding also provides the important first step in a materials recovery system of "liberating" the various components from each other. Ferrous metals are then magnetically extracted. As new separation techniques are demonstrated to be technically feasible, they may be added to the system.

Complement to Energy Recovery Systems

Technology is being developed to recover various noncombustible materials either before or after energy recovery takes place.

Total Materials Recovery Systems

Systems are now being developed which recover as many of the components of the waste as are economically feasible. An example of this approach is the EPA demonstration project in Franklin, Ohio.

ADVANTAGES

A community can receive the following benefits through implementation of a materials recovery system.

Resource Conservation

Net environmental benefits can be achieved through materials recovery. Through recycling, the drain on limited natural resources is reduced. Also the manufacturing of products from recycle materials has been shown to be less polluting in most cases and requires less energy than manufacturing which relies on virgin materials.

Reduced Landfill Usage

Removal of materials from the solid waste stream for recycling will reduce the quantity of waste which must be disposed of.

Lower Disposal Costs

The sale of recovered materials will probably never result in actual profits for the waste management system. However, enough revenues may be generated to pay not only for the increased cost to the system of separating and marketing the materials but also for some of the cost of the overall disposal operation.

Citizen Support

The implementation of a recovery system is in consonance with mounting citizen concern about resources and the environment. Siting should be less of a problem for resource recovery facilities than for conventional disposal facilities.

DISADVANTAGES AND RISKS

Still-Emerging Technology

The degree of technological risk varies with the complexity of the system. Adding a magnetic separator to pull out ferrous metals at a shredding/landfilling operation should have a minimal risk, but in general the methods of recovering other materials that are marketable are still in stages of development. There is a great deal of work going on in this field in private industry, universities, municipalities, and the Federal Government. Many concepts are now being demonstrated; some of the demonstrations are described later in this chapter.

Economic Risks

Due to the newness of this field, well-documented cost and performance information on commercially available equipment that is actually being used to process solid waste is largely unavailable. Estimates of economic feasibility are primarily based on projected maintenance costs, the separation system's recovery rate or yield, and an assumed value for the product. These three items in particular should be scrutinized during the decision-making process. The economic evaluation also depends, of course, on capital costs, operating costs, and product transportation costs, but these estimates are generally more reliable than the previous three.

Marketing Problems

The payoff for a materials recovery system is the sale, at a reasonable price, of the extracted materials. Marketing tactics and negotiations with purchasers represent unfamiliar waters for most municipalities, however. The community should prepare itself with as much knowledge as possible about the marketplace they are about to enter. Of particular importance are the precise material specifications of the purchaser. These should be closely compared to the anticipated quality of the separated materials. Prior to the commitment of capital funds the community should secure as binding and explicit a commitment as possible from the purchaser. The best would be a contract which specifies acceptable quantity, quality, price, transportation or transfer mechanism, and term of the agreement.

The risks noted above may be reduced, but never eliminated, through the use of a private operating contractor or system promoter. The execution of an equitable contract with the private sector is not a straightforward task here either, but this option may reduce the community's headaches in some areas and shorten the implementation period. The municipality should be aware, however, that it can never totally eliminate the risk factors, and therefore the responsibility to scrutinize and evaluate these factors continues. Finally, the community should expect to pay something extra for any special services provided or any risks shared by the private sector.

PREREQUISITES TO SUCCESSFUL IMPLEMENTATION

Markets

A comprehensive market survey specific to the local area must indicate that the recovered materials will in fact be purchased at a reasonable price.

Early discussions with potential buyers are extremely important in order to make sure that the separation system produces materials of sufficient quality and quantity to be useful to the buyer. Any conclusions reached should be reinforced through a contractual agreement before committing funds to construct the facility.

Shredding

Even the simplest form of mechanized materials recovery, ferrous metal extraction, requires at least some processing of the solid waste stream to open up paper and plastic bags and "liberate" the tin cans. This function is performed by some form of shredding operation, which can vary from an extremely coarse shredder, little more than a bag opener, to a more sophisticated shredder that reduces all the incoming materials to particles less than a cubic inch in size.

This size reduction equipment can be quite costly, ranging up to hundreds of thousands of dollars. The many benefits that shredding alone offers to a solid waste handling and disposal system are sufficient to justify the capital expenditure in some cases.

Current economic projections indicate that the revenues from the sale of the recovered materials cannot completely offset the added cost of the shredding operation Therefore, to add a materials recovery system onto a disposal operation that does not already include a shredder would increase the net costs of the whole operation. This increase must be weighed against the auxiliary benefits that shredding provides.

If the solid waste management program has already justified the need for a shredder to improve the disposal operations, then the additions of various levels of materials recovery appear to be very attractive. That is to say, the revenues generated can more than offset the equipment and operating costs required to perform the separation.

Minimum Size

Capital-intensive facilities require large throughputs to achieve reasonable processing costs per ton. Even the ddition of a shredder alone could probably not be justified by a small community with less than, say, 150 tons of solid waste per day. The larger the facility—up to 2,000 or more tons per day—the lower the cost per ton. This type of materials recovery system may thus be ruled out for smaller communities unless several combine their wastes at one location for processing. Separate collection of newspaper is not so constrained and may be appropriate for even the smallest communities.

TYPES OF RECOVERY ACTIVITIES

Manual Separation

Handpicking is a long-used form of separation. In this type of operation, a conveyor passes the solid waste by a group of workers who pick out the valuable components by hand. This method has a number of serious drawbacks. It can be a very costly form of separation. Secondly, it is a limited separation because the pickers can usually extract only the bulky materials. Finally, there are potential health and safety hazards, and handpicking is not a job that attracts conscientious workers. Therefore, EPA does not recommend this practice.

Handpicking of bundled newspapers is nevertheless being promoted by the National Center for Resource Recovery and Americology, Inc. They propose that homeowners bundle their newspapers before they set them out for collection. The bundles are thrown in the truck with the rest of the wastes, and, at the processing facility, these bundles are handpicked from a conveyor and set aside to be sold.

Composting

Composting of municipal solid waste has been practiced in Europe and the United States for many years. European activity in composting has included research in such diverse areas as engineering technology, public health and pathogen survival, and use in strip mine reclamation, in vineyards, and in general agriculture. The technology of composting is well advanced, and there are no real technological barriers to making compost.

In the United States, composting plants have been established in various communities over the last 20 years. In general, these plants have met with little success and most have closed. The major problem for these plants is the lack of a viable market for the compost. Currently, only one plant, Altoona FAM, Inc., in Altoona, Pennsylvania, is known to be operating on a regular basis.

In the Fairfield-Hardy process used at Altoona, solid waste is ground in a wet-pulper and passed through dewatering presses before it is fed into the digestor for a 5-day decomposition cycle. The material is stirred in the digestor by augers suspended from a rotating bridge in the circular tank. Air is provided by means of a blower and air pipes embedded in the floor of the tank. This digestion system of Fairfield Engineering Company, compared with other composting techniques, appears to offer a superior engineering design, a more automated operation, and a superior humus product.

Ferrous Metal Recovery

Ferrous metal recovery is a significant revenue generator for three reasons. There is a significant quantity of ferrous metal, around 7 percent, in the solid waste stream. The value of this metal is typically $12 to $20 per ton. And, ferrous metals are relatively easy to extract.

While the technology for extracting ferrous metals is readily available, upgrading of the separated metal may also be required for salability in some cases. Initial attempts at ferrous metal recovery have resulted in products that were contaminated with paper and other organic materials. Some purchasers found the density undesirable.

There are three basic markets for recovered ferrous metals: reuse in a steelmill, in precipitation of copper from low-grade copper ore, and in the detinning industry, which recovers the valuable tin from the tin cans.

Each of these markets has specific requirements for the ferrous scrap that they will buy. The technology for upgrading to meet these requirements is now being developed. It is important to note that these market constraints may be significant factors in selecting the type of shredder to be used in the initial processing step. Some shredders such as ring mills and wet-pulpers tend to ball up the tin cans, which makes them less desirable for copper precipitation and detinning but acceptable for the steel industry.

Impact of Beverage Container Legislation. Several proposals to reduce the generation of solid waste are being introduced in State and local legislatures. The most popular of these requires a mandatory deposit for beverage containers and would have an impact on the amount of steel, aluminum, and glass containers discarded in the waste stream (see chapter on Reducing Waste Generation). Steel cans would probably be reduced by 15 percent. A 1,000-ton-per-day facility recovering ferrous scrap could realize a "yield loss" of approximately 2,000 tons per year of scrap cans, and the annual revenue losses would amount to $40,000 at $20 per ton. On a per ton basis, revenue from ferrous metals would be reduced from $1.25 to approximately $1.06 for each ton of solid waste processed.

Paper Recovery

Paper represents 30 to 35 percent of municipal wastes, and the sale of the various paper fractions can be a major source of revenue where markets can be found. It is important to note that paper has a higher value when it is reused as paper than when it is used as an energy source.

While source separation and separate collection constitute the main means of paper recovery, there are also two types of mechanized recovery from mixed wastes: wet separation and dry separation. Wet separation has been demonstrated in Franklin, Ohio, as described below. The marketability of the material recovered by this method is still limited. Operational systems for dry separation of paper fibers exist in Europe, and there are attempts underway to develop feasible systems in this country.

In paper recovery as in all other resource recovery activities, the availability and stability of markets are necessary for continuing success. The issues related to wastepaper marketing are discussed in the chapter on Source Separation.

Glass and Aluminum Recovery

Glass and aluminum recovery systems are now being developed, but their technical and economic viability is uncertain at this time. The EPA demonstration project in Franklin is investigating this issue.

Glass represents between 6 and 10 percent of the solid waste stream. Its value is between $12 and $20 per ton. Color-sorted cullet may sell for more, depending on the market location. The real advantage to color-sorted glass is that there are at least twice as many markets for it as for mixed-color glass. However, the technical and economic feasibility of color-sorting glass to acceptable quality levels has not yet been demonstrated. Potential uses for glass in construction materials exist but have not yet been developed to a significant degree.

In glassmaking, cullet is in some ways preferable to virgin raw materials because its use reduces fuel consumption and refractory wear. The industry generally limits the use of cullet in the glass formula to approximately 20 percent by weight, although 80 to 100 percent cullet formulations have been used.

Aluminum makes up less than 1 percent of the solid waste stream, but this component has an extremely high value of $200 or more per ton. Aluminum therefore could be an important revenue generator, and much technology development is underway to separate and concentrate this material. Because of its value, the recovered aluminum is not expected to pose any significant marketing problems.

Although the economic viability of aluminum recovery technology is uncertain at present, there are plans to include aluminum recovery in some of the facilities which will be built within the next 2 to 3 years. These include a new plant to be built in Ames, Iowa, in 1975 to recover ferrous and nonferrous metals and aggregate from raw waste; a dry separation plant to be built in New Orleans in 1975 for recovering glass, metals, and paper; and a dry-shredded-fuel recovery facility in Bridgeport, Connecticut, scheduled to begin operation in 1976.

Impacts of Beverage Container Legislation. It is estimated that beverage container legislation can reduce the glass content in the waste stream (currently about 9 percent) by a third. At current market prices ($20 per ton), the reduction in glass recovery would mean revenue losses totaling $100,000 each year, or $0.40 per ton of raw waste processed, for a 1,000-ton-per-day plant. At this point, the impact of the loss on glass recovery feasibility is uncertain since the basic economics are not yet known.

A beverage container deposit would reduce the aluminum content in waste by 30 percent. For a 1,000-ton-per-day recovery plant, this would reduce the yield of aluminum by roughly 300 to 400 tons per year, which, at prices of $300 to $400 per ton, translates to $90,000 to $160,000 of lost revenue. On the basis of tonnage of raw waste input, the reduction in revenue would be $0.34 to $0.61 per ton. At this time, the economics of aluminum recovery are too uncertain to accurately judge the impact of deposit legislation.

EPA PILOT SYSTEMS

Wet Separation and Disposal

System Description. Franklin, Ohio's solid waste processing facility, developed by the Black Clawson Company, has a design capacity of 150 tons per 24-hour operation and is made up of three subsystems: a solid waste disposal system that includes a ferrous metal separator, a paper fiber recovery system, and a glass and aluminum recovery system (Figure 9).

The disposal system, called the "Hydrasposal System," consists primarily of a wet-pulper, a liquid cyclone, and a fluidized bed incinerator. Wastes delivered to the Franklin plant by private contractors and individual citizens are fed by a conveyor into the pulper. The pulper is somewhat like a kitchen sink disposal unit; it consists of a tub 12 feet in diameter with a high-speed cutting blade in the bottom driven by a 300-horsepower motor. Water is mixed with the solid wastes in the pulper, and all soft and brittle materials are ground into a slurry. Large pieces of metal, cans, and other non-pulpable materials are thrown out the side of the pulper and down a chute that leads to a specially designed bucket elevator, the "Junk Remover." These materials are

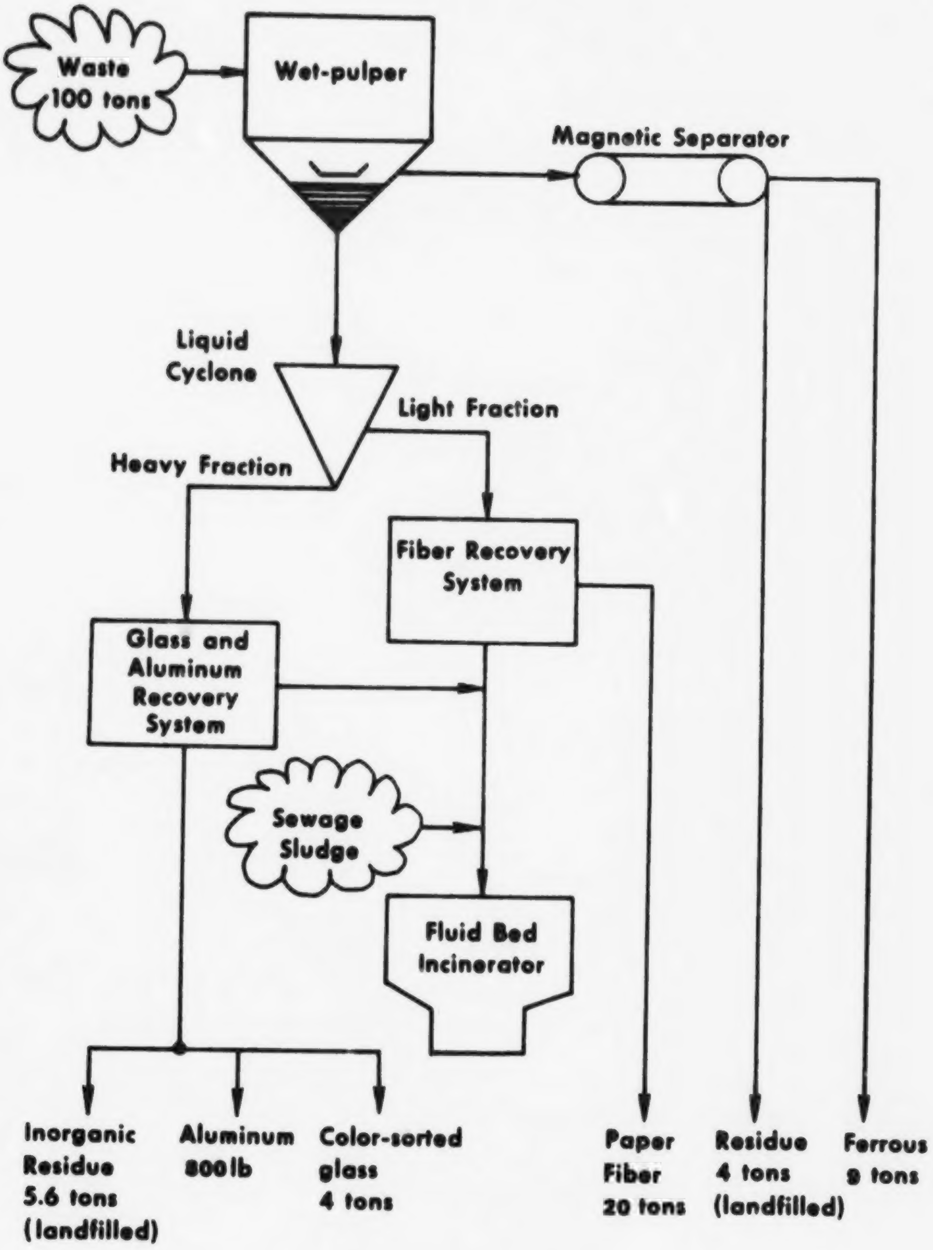
Waste
100 tons
Wet-pulper
Magnetic Separator
Liquid Cyclone
Light Fraction
Heavy Fraction
Fiber Recovery System
Glass and Aluminum Recovery System
Sewage Sludge
Fluid Bed Incinerator
Inorganic Residue 5.6 tons (landfilled)
Aluminum 800 lb
Color-sorted glass 4 tons
Paper Fiber 20 tons
Residue 4 tons (landfilled)
Ferrous 9 tons

FIGURE 9. The Franklin, Ohio, pilot plant for the demonstration of a wet separation and disposal system consists of three disposal and recovery subsystems: a solid waste disposal system that includes a ferrous metal separator, a paper recovery system, and a glass and aluminum recovery system.

washed, then conveyed under a magnetic separator where steel cans and other ferrous objects are separated for recycling. The nonmagnetic materials are buried in the plant's sanitary landfill.

The slurry, which contains almost all of the organic materials plus most of the glass, small pieces of metal, ceramics, and much of the aluminum, leaves the wet-pulper through a perforated plate beneath the blade. The slurry is then pumped to the liquid cyclone, where the heavier materials such as glass, metals, ceramics, and wood are separated from the lighter fibrous material by centrifugal action.

After the metals and glass are removed, the slurry moves into the fiber recovery or "Fibreclaim" system. In this process the longer paper fibers that can be used in making paper are mechanically separated. The separation is accomplished by a series of screens that isolate the paper fiber from the coarse organic materials, such as rubber, textiles, leather, and yard wastes; and the fine contaminants, such as food waste, paper coatings and fillers, shorter paper fibers, and the very small pieces of glass or dirt. The recovered fibers are pumped to the Logan Long Company, about a half mile away, where they are used to make felt paper for asphalt roofing shingles.

The heavier materials ejected from the liquid cyclone are conveyed to the glass and aluminum recovery system, which was developed by the Glass Container Manufacturers Institute. The system uses a series of screening and classifying operations to extract extraneous materials and produce an aluminum-rich concentrate, which can be upgraded for recycling, and a glass-rich stream. The stream of glass particles is passed through an optical sorting device, developed by the Sortex Company of North America, which separates the glass into clear, amber, and green fractions suitable for use in making new bottles.

The nonrecoverable combustible material from the fiber recovery system and the glass recovery system are combined and sent to the fluid bed incinerator, the final step in the Hydrasposal System. The incinerator is a vertical cylindrical unit with a 25-foot inside diameter and was supplied by Dorr Oliver, Inc. Air is blown upward into this unit through a layer of hot sand. The organic residue is thus blown into the fluidized bed of sand, where the combustibles burn completely. The exhaust gases pass through a venturi scrubber that removes the ash particles. The gases discharged to the atmosphere meet Federal air pollution control standards.

Status of Project. The Hydrasposal and fiber recovery systems began operating in June 1971. The plant is now in daily commercial operation, processing about 50 tons of municipal solid waste in one 8-hour shift per day. It is the sole solid waste disposal facility for the city of Franklin and the adjacent areas. The glass and aluminum recovery system began operating in September 1974, but technical problems have so far prevented its continuous operation; the revenues from the sale of these products may eventually reduce the net cost of the operation (Table 37).

Economics. On the basis of approximately 3 years' operating experience in Franklin, the wet separation of solid wastes into recoverable products appears to be an economically attractive resource recovery and waste disposal option. This, of course, is a judgment that depends upon the costs of alternative means of disposal. The Black Clawson system will not break even without charging a fairly high dump fee to the users, but indications are that it will be cost-competitive with incineration and in some situations may even be competitive with sanitary landfilling where there is a long haul involved.

Capital and net cost projections have been made for 150-, 500-, and 1,000-ton-per-day plants based on the Franklin operating experience (Tables 38 and 39). The capital cost for a 1,000-ton-per-day facility would be on the order of $20 million. Typical projected costs per ton for operating the system, including amortization at 8 percent for 20 years, are about $19, while the anticipated revenue is around $12 per ton. This yields a net cost of around $7 per ton.

Incinerator Residue Separation

The U.S. Bureau of Mines and the Raytheon Service Company have developed and demonstrated on a pilot scale a technically feasible method for recovering the metal

TABLE 37

QUANTITY, QUALITY, PURCHASERS, AND PRICES OF MATERIALS RECOVERED FROM MUNICIPAL SOLID WASTE AT THE FRANKLIN, OHIO, PILOT PLANT*

Product	Amount recovered as approximate percent of incoming solid waste (dry weight basis)	Quality	Purchaser	Price per ton†
Ferrous metals	9	Roughly equivalent to a No. 2 bundle Generally free of nonmetallics Density may need to be upgraded	Armco Steel Company, Middletown, Ohio	$13-25
Paper fiber	20	Generally considered a lower grade paper fiber Color, grease, and bacterial contaminants are similar to those of mixed wastepaper but fibers are longer and there is less shrinkage Suitable for use in making roofing felt and other construction papers Contaminants can be removed and upgraded for use in higher grades of paper	Logan Long Roofing Plant, Franklin, Ohio	25-65
Glass	4	Expected to be clean and sorted by color	Various glass bottle manufacturing plants in the area	12-2
Aluminum	0.3	Quality varies at present Development work still underway	Aluminum industry	200

*ARELLA, D. G. Recovering resources from solid waste using wet-processing; EPA's Franklin, Ohio, demonstration project. Environmental Protection Publication SW-47d. Washington, U.S. Government Printing Office, 1974. 26 p.

†Price at the plant; transportation from the plant is paid for by the purchaser.

and mineral values from incinerator residues. The process uses conventional proven mineral engineering equipment along with a series of shredding, screening, and magnetic separation procedures to produce clean ferrous metals, aluminum, copper/zinc composites, glass, and an aggregate for road construction. The system can also be adapted to handle noncombustible waste fractions other than incinerator residue, such as the heavy fraction from an air classifier.

This system was to be demonstrated by the city of Lowell, Massachusetts, with EPA funding assistance, but the project has been cancelled at the city's request. The city's action followed its decision to close down its

TABLE 38

PROJECTED CAPITAL COSTS FOR FRANKLIN-TYPE WET-PULPING PLANTS WITH CAPACITIES OF 150, 500, AND 1,000 TONS PER DAY, 1975[*]

Component	Facility size		
	150 TPD	500 TPD	1,000 TPD
Weighing and receiving	$254,800	$1,103,000	$2,051,000
Pulping, separation, and dewatering	876,400	4,289,000	7,987,000
Fluid bed incinerator	938,000	3,291,000	6,133,000
Fiber recovery	712,600	1,912,000	3,551,000
Total	$2,781,800	$10,595,000	$19,722,000

[*] SYSTEMS TECHNOLOGY CORPORATION. Technical and economic evaluation of the Franklin, Ohio, resource recovery facility. Washington, U.S. Environmental Protection Agency. (In preparation.)

TABLE 39

PROJECTED NET COSTS PER TON FOR FRANKLIN-TYPE WET-PULPING PLANTS WITH CAPACITIES OF 150, 500, AND 1,000 TONS PER DAY, 1975[*]

Costs	Facility Size		
	150 TPD	500 TPD	1,000 TPD
Facility expense[†]	$9.34	$10.46	$9.73
Operating expenses	15.22	9.96	9.32
Total expenses	24.56	20.42	19.05
Income per ton of waste processed:[‡]			
Paper fiber	8.06	8.06	8.06
Ferrous metal	2.40	2.40	2.40
Sludge disposal	1.75	1.75	1.75
Total income	$12.21	$12.21	$12.21
Net cost	$12.35	$8.21	$6.84

[*] SYSTEMS TECHNOLOGY CORPORATION. Technical and economic evaluation of the Franklin, Ohio, resource recovery facility.

[†] Based on 20-year depreciation.

[‡] Assumes that the recovered ferrous metal sells for $25 per ton, and recovered paper fiber sells for $42 per ton. When the glass and aluminum recovery system is in full operation, the revenue from the sale of these products will reduce the net cost.

incinerator rather than undertake very expensive capital improvements needed for pollution control. Nevertheless, much of the experience and information gained in planning the project is still considered valuable and will be documented in a report which should be available by late 1975. Capital costs for a facility processing 750 tons of residue per 24-hour day, roughly equivalent to 2,000 tons of solid waste input to the incinerator, would be on the order of $4 million. Projected operating costs, which include amortization at 6 percent for 15 years, are $17.80 per ton of residue. The projected revenue is around $17.25 per ton of residue input, which yields a net cost of $0.55. The revenues are dependent upon the ability to market the products of the system.

Some empirically derived costs for a plant of this type have been prepared by the Bureau of Mines and may be obtained by requesting the Bureau of Mines Information Circular No. IC 8533, "Cost Evaluation of a Metal and Mineral Recovery Process for Treating Municipal Incinerator Residues."

Other Separation Systems

EPA's other resource recovery projects are demonstrating various unit operations, such as magnetic separation and air classification, for separating and recovering materials. Virtually all current or proposed energy recovery facilities also involve materials recovery to a significant degree. There are numerous companies involved in private research efforts toward developing resource recovery systems. Generally the approach has been to follow the shredder with magnetic separation and then some form of air classification to concentrate the heavy and light fractions. The heavy fraction is further processed in one of a number of types of equipment that rely on different densities to perform the next separation. The products from the heavy fraction are generally limited to ferrous metals, glass, and aluminum. The light, combustible fraction would be either landfilled, put through a paper recovery process, or used as a fuel in a boiler.

Some of the organizations that are developing these systems are listed here, and additional information may be obtained directly from them:

U.S. Bureau of Mines
College Park, Maryland 20740

National Center for Resource
Recovery, Inc.
1211 Connecticut Avenue, N.W.
Washington, D.C. 20036

Combustion Power Company
Menlo Park, California 94025

American Can Company
Americology System
American Lane
Greenwich, Connecticut 06830

Raytheon Company
12 Second Avenue
Burlington, Massachusetts 01803

Garrett Research and Development
Company, Inc.
1355 Carrion Road
LaVerne, California 91750

Grumman EcoSystems Corporation
1111 Steward Avenue
Bethpage, New York 11714

CONCLUSIONS

Complement to Energy Recovery Systems

Materials recovery systems are not incompatible with energy recovery systems. Almost all resource recovery systems being developed include the recovery of both materials and energy. Generally the preferred approach is to recover as many of the materials as the technology and markets can justify and then to recover the energy value in the remaining combustible fractions. This approach can provide a nearly comprehensive resource recovery system by recovering over 90 percent of the material or energy values in the solid waste stream.

Some of the various resources available in our solid wastes represent significant quantities in relation to our national supply and demand for these materials. Also, we have found that manufacturing processes using recycled materials generally require less energy and create less pollution than processes using virgin materials.

Technological and Marketing Risks

Implementation of materials recovery systems has significant risks which should be fully identified prior to commitment of capital funds. Municipalities should be aware that resource recovery concepts offer tremendous promise, but that their decisions are being made at the forefront of existing technology and that marketing of the materials represents a new field for most municipalities.

Ferrous metal recovery operations carry the least technological risk, while the more complex separation systems are less developed. The Franklin, Ohio, demonstration plant is the most highly developed materials recovery system, but the final evaluation of the plant is just now being completed. Many other systems are being developed, and some of them should be ready for implementation with minimized risk in the next few years.

Marketing Groundwork Necessary

Adding a ferrous metal recovery operation onto an existing shredding facility offers a high degree of probable success if markets are identified and secured ahead of time. Currently over 25 communities are recovering and selling ferrous metals in this type of operation, but there have also been a num

ber of dismal failures in cases where the need for advance marketing work was overlooked. EPA cannot emphasize too strongly the need for this marketing groundwork as the first stage toward implementing any resource recovery system.

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HERBERT, W., and W. A. FLOWER. Glass and aluminum recovery in recycling operations. *Public Works*, 102(8):70, 110, 112. Aug. 1971. Reprinted, [Cincinnati], U.S. Environmental Protection Agency, 1972. 2 p.

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MOREY, B., and S. RUDY. Aluminum recovery from municipal trash by linear induction motors. Presented at 103rd Annual Meeting, American Institute for Mining, Metallurgical and Petroleum Engineers, Dallas, Feb. 24-28, 1974. 15 p.

SKINNER, J. H. The demonstration of systems for recovering materials and energy from solid waste. Presented at National Materials Conservation Symposium, National Bureau of Standards, Gaithersburg, Md., Apr. 29, 1974. [Washington], U.S. Environmental Protection Agency, 1974. 20 p.

conservation, environmental effects decisions collection, transport, processing, disposal criteria cost, institutional factors, resource conservation.

SANITARY LANDFILLING

conservation, environmental effects decisions collection, transport, processing, disposal criteria cost, institutional factors, resource conservation.

Sanitary landfilling is an engineered method of disposing of solid wastes on land in a manner that minimizes environmental hazards and nuisances. At a site that is carefully selected, designed, and prepared, the wastes are spread in thin layers, compacted to the smallest practical volume, and, at least at the end of each operating day, covered with earth, which is also compacted.

Every community needs access to a sanitary landfill for environmentally safe disposal of its solid wastes. The rate at which landfill capacity is used up can be reduced through resource recovery, incineration, baling, shredding, and measures to slow down the generation of waste. Resource recovery and waste reduction measures are also vital for conservation of resources. Even if widely applied, however, such practices cannot eliminate solid waste altogether, and communities will continue to require a means of final disposal.

SITE SELECTION

Obtaining a proper site is perhaps the most difficult problem in the development of a sanitary landfill. Opposition by local citizens can effectively eliminate otherwise acceptable proposed sites. Such opposition often arises because:

1. Citizens are not familiar with sanitary landfills and equate them with disposal operations they are familiar with—open burning dumps. A lowering of property values is a major concern.
2. Citizens are unaware that public disposal facilities are needed even where resource recovery is practiced.
3. It may be necessary to use prime land for the landfill. Citizens may object to the temporary removal of the land from revenue-producing use and to having the disposal operation in a visible location. Some types of marginal lands (swamps, flood plains, gravel pits, etc.) which have been used in the past have generally been unsatisfactory as landfill sites.

To allay such opposition, an intensive public information campaign is an essential early step in site acquisition. Supportive informational materials are available from EPA's Office of Solid Waste Management Programs, including a film, *Sanitary Landfill—You're the Operator*, and publications, such as *Sanitary Landfill Facts*.

In choosing a location for a landfill, consideration should be given to the following variables:

1. Hydrogeology and surface waters.
2. Cover material availability.
3. Accessibility of site to collection vehicles (including traffic obstacles such as traffic lights, bridges, underpasses, railway gates, etc.), and haul distance and time.
4. Public opposition.

As the procedures for site evaluation, acquisition, zoning, environmental impact assessment, and design often require considerable time, officials are encouraged to plan far ahead for their sanitary landfill needs. Environmentally acceptable sites with all required approvals and permits should be available well before they must be used in order to assure continuous safe disposal of waste. Communities contemplating the application of new resource recovery technologies still must provide sanitary landfill sites for the many nonprocessables and residues.

Costs

The cost of a sanitary landfill consists of the initial investment associated with acquiring the site and equipment and with construction, and the operating costs.

Initial Investment

The magnitude of the initial investment depends on the size and complexity of the landfill. The major items normally covered by the initial investment are:

1. Land
2. Planning and engineering:
    - a. Site investigation
    - b. Design, plans, specifications
    - c. Permit application
3. Site development:
    - a. Land development—clearing, landscaping, drainage, etc.
    - b. Access roads
    - c. Fencing, signs
4. Facilities:
    - a. Administration
    - b. Equipment maintenance
    - c. Sanitary facilities, utilities
    - d. Weight scales
5. Equipment—tractor, scraper, etc.

In most cases, the initial investment for land can be recovered on completion of the sanitary landfill through subsequent development or use of the land. A sanitary landfill may even increase the value of some plots of land by making them more suitable for recreational or agricultural uses.

Planning and design costs vary, depending on the extent of effort required. At a 50-acre urban site in the Midwest, these costs amounted to about $90,000 (1970); prorating over the site capacity of 496,000 tons yields a unit cost of $0.18 per ton. A 23-acre, 135,000-ton capacity site in the West required costs of $11,000, or $0.08 per ton (1975). Another western site of 160 acres and 5.8-million-ton capacity required costs of $11,000, or $0.002 per ton.

There is a trend among States to require operators of all sites to apply for and obtain permits to operate. State permit programs are desirable in that they provide (1) a consistent and rigorous check on the selection and design of sanitary landfill sites to minimize environmental impact and (2) an efficient direct enforcement tool to ensure that high quality operations are maintained. In most States requiring permits, application procedures are well defined. Generally, the applicant must submit for approval information on the site investigation and engineering design. Engineering and legal fees to prepare the information for permit application (Table 40) seldom amount to less than $15,000. Litigation and prolonged hearings can raise fees to the $100,000 range. Permit application fees range up to $1,000. Local permit procedures are less predictable, but may require costs of $500 to $5,000, especially where zoning changes or variances are sought.

Site development costs reflect the site's size and the improvements required before it can be used (Table 41). The 50-acre urban site mentioned above required extensive improvements to protect against ground water pollution. Site development costs amounted to about $400,000, or $0.84 per ton. A site serving a rural southern county required an expenditure of $22,400 for development. Site development costs of about $430,000 were incurred at a 1,500-acre site in the Southeast which required special construction for ground water protection. Another southern site required costs of about $28,300 (1975); capacity of the 27-acre site is 171,500 tons. A 23-acre western site having a capacity of 135,000 tons incurred costs of $24,000. Costs for a 160-acre, 5.8-million-ton capacity site in the West were reported as $24,102 (1975). At some sites, monitoring wells are required for detection of ground water pollution. Such wells can usually be installed for $8 to $12 per foot of depth (cased).

Facilities costs amounted to about $100,000 ($0.21 per ton) at the midwestern site, $13,500 at the rural southern site, and

$150,000 at the southeastern site (1973). Facilities at the 27-acre southern site cost about $13,000 (1975). Facilities costs for the two western sites of 23 and 160 acres were $51,000 and $45,000, respectively (1975).

Equipment costs vary with size and design (Table 42). The costs should be depreciated over about 8,000 operating hours. At 2,000 operating hours per year, the equipment life would be 4 years; if the depreciation is stretched to 5 years, equity value, in most cases, would be significantly lessened.

TABLE 40

SANITARY LANDFILL PERMIT APPLICATION COSTS, BY DESIGN CAPACITY OF SITE, 1975

(In thousands of dollars)

Item	Design capacity in tons per day			
	40	100	300	Greater than 300
Engineering design*	12	18	25	30+
Survey	6	8	10	10
Borings	5	8	15	25
Legal work	4	6	10	10+

*If an environmental impact report is required and/or unfavorable hydrogeological conditions are encountered, site development costs may be increased substantially, perhaps even dwarfing expected engineering design costs.

TABLE 41

INITIAL COSTS FOR THREE SANITARY LANDFILLS, 1975

Item	Site 1 (50 TPD)		Site 2 (150 TPD)		Site 3 (300 TPD)	
	Total (in thousands)	Cost per ton	Total (in thousands)	Cost per ton	Total (in thousands)	Cost per ton
Planning and design	$20	$0.10	$16	$0.07	$130	$0.06
Site development	10	.05	1		624*	.30
Facilities	52†	.26	7‡	.03	241	.12
Equipment	329	1.64	226	1.02	1,033	.50
Total	$411	$2.05	$250	$1.12	$2,028	$0.98

*Includes 3-mile paved road.
†Includes fencing.
‡No fencing.

Operating Cost

The operating cost of a sanitary landfill depends mainly on the cost of labor and equipment, the method of operation, and the efficiency of the operation. The principal items in operating cost are:

1. Personnel
2. Equipment:
    a. Operating expenses—gas, oil, etc.
    b. Maintenance and repair
    c. Rental, depreciation, or amortization
3. Suitable earth cover (cost depends on availability, type of soil, and hauling expenses)
4. Administration and overhead
5. Miscellaneous tools, utilities, insurance, maintenance of roads, fences, facilities, drainage features, etc.

Operating costs in 1974 for three sanitary landfills in California were reported as $4

TABLE 42

APPROXIMATE SANITARY LANDFILL EQUIPMENT PRICES, 1975

Type	Weight (tons)	Approximate price
Track loader	8-11	$33,000
	12-16	50,000
	21-23	78,000
	33	120,000
Track dozer	7-12	30,000
	14-20	75,000
	26-32	115,000
	41-42	170,000
	51	240,000
Wheel loader	5-15	45,000
	16-27	90,000
	30-34	120,000
	53-58	178,000
	70-100	275,000
Wheel dozer	17-18	65,000
	28-33	115,000
	35-47	147,000
	72	250,000
Compactor	11-19	65,000
	20-33	115,000
	38-40	140,000

per ton (72 tons per day), $5.40 per ton (33 TPD), and $8 per ton (18 TPD). In 1975, a 900-TPD site in Washington operated at a cost of $1.50 per ton, while a 15-TPD site in Indiana reported costs of $7.20 per ton. A site in northern Virginia handles 900 TPD at a cost of $2.75 per ton.

OTHER CONSIDERATIONS

Land Requirements

The land area required is primarily dependent upon the character and quantity of the solid wastes, the efficiency of compaction of the wastes, the depth of the fill, and the desired lifetime of the site as a landfill.

National estimates for 1973 indicate that the total residential and commercial solid waste generation rate per person per day is approximately 3.5 pounds. However, the volume requirement for a sanitary landfill should be determined on the basis of specific information developed for the individual project. Given a solid waste density of 1,000 pounds per cubic yard in place, and one part (volume) earth cover to four parts solid waste, a population of 10,000 people would require approximately 10 acre-feet of space per year for residential and commercial wastes. Actual densities may vary from about 800 to 1,200 pounds per cubic yard, and cover ratios may vary from 1:1 to 1:4.

This volume requirement may be significantly reduced where wastes are processed for volume reduction prior to disposal in the sanitary landfill. Incinerators achieve average weight and volume reductions of 75 and 90 percent, respectively. Baling can achieve densities of 1,000 to 1,750 pounds per cubic yard. Size reduction measures such as shredding or grinding also help to eliminate voids and aid compaction. Shredded solid waste placed in a sanitary landfill can have a density 25 percent greater than that of unprocessed solid waste where the same compaction equipment and techniques are used. In special situations where site geology and hydrology permit, shredded waste may be disposed of on the land without the daily cover required for unprocessed waste. Where soil for the covering is obtained offsite, doing without the cover will in effect increase by about 20 percent the site volume that can be used for solid waste disposal.

Vector Control

In a properly operated and maintained sanitary landfill, insects and rodents are not a problem. Good compaction of wastes and cover material is the most important factor in achieving vector control. A compacted earth cover of at least 6 inches in thickness, applied daily, is recommended for preventing the emergence of flies and for discouraging rodents from burrowing through the fill. Good housekeeping and daily covering of unprocessed solid wastes are musts for vector control. In the case of shredded waste, landfilling without cover does not seem to result in vector problems.

Water Pollution

Under certain hydrogeological conditions, the disposal of solid wastes on land can cause chemical and microbiological contamination of ground and surface waters. Contamination results from the leaching of substances from the solid waste by ground or surface waters, including infiltrating precipitation, that come in contact with the wastes. In many cases, the leachate has traveled to and polluted surface streams and ground water aquifers. The sanitary landfill method of disposal can eliminate or minimize such effects.

Leachate production is enhanced by (1) exposure of uncovered wastes to precipitation and surface runoff, (2) deposition of solid wastes into bodies of ground or surface waters, and (3) use of sites having direct hydrologic connection to underlying ground water.

Proper planning and site selection, combined with good engineering design and operation of a sanitary landfill, can normally minimize the possibility of either surface or ground water pollution. Some common preventive measures are: (1) locating the site at a safe distance from streams, lakes, wells, and other water sources; (2) avoiding site location above the kind of subsurface strata that will lead the leachate from the landfill area to water sources, e.g., fractured limestone; (3) providing suitable drainage to carry the surface water away from the site; (4) tightly compacting the solid waste in the fill; (5) providing a compacted daily cover sloped to encourage runoff; (6) collecting any leachate generated and treating it to remove contaminants before releasing it to the environment; and (7) never depositing solid waste in direct contact with surface or ground water.

Guidance on proper site selection and on designs which can be used to improve site acceptability is available from the literature, State solid waste management agencies, various consulting engineering and hydrogeologic science firms, the Soil Conservation Service of the U.S. Department of Agriculture, and EPA's Office of Solid Waste Management Programs.

Equipment

A wide variety of equipment is available from which the proper type, size, and number may be selected for a particular operation. Factors to be considered in selecting equipment include:

- Solid waste types, quantities, and times of delivery
- Soil types and sources
- Climate
- Availability and dependability of maintenance and repair service
- Method of site operation (trench, slope, area, etc.)
- In-place densities desired
- Amount of excavation required
- Experience and preference of site designer and equipment operators

Once the individual requirements of the particular sanitary landfill have been defined, guidance on equipment selection can be obtained from consulting engineers and equipment manufacturers and dealers. Another excellent source of guidance is experienced sanitary landfill operators.

The most common equipment used on sanitary landfills is the crawler dozer or crawler loader. Crawler units are versatile and can perform a variety of operations: site preparation, spreading, compacting, covering, and construction and maintenance of access roads. They are all-weather machines with excellent flotation and tractive ability. Note, however, that the flotation design does not allow the crawlers the same compaction ability inherent in a sanitary landfill compactor, which is designed primarily for compaction.

Crawler dozers are well suited to area fill operations due to their ability to excavate and economically bulldoze cover material up to 300 feet. The larger trash or landfill blade can be used in place of the straight dozer blade, thereby increasing the volume of solid waste which can be dozed.

Crawler loaders are often used on trench fills due to their excavating ability. They are also able to compact directly adjacent to the vertical wall of the trench. Crawler loaders also have the ability to lift materials off the ground for carrying. They can economically provide cover material from about 300 feet. Loaders can be fitted with a device which allows the bucket to be very easily detached; the machine is then able to attach and carry bulk solid waste containers.

Rubber-tired machines are used where mobility is important. Due to their speed, they often economically transport cover material from distances of 600 feet or more. Rubber-tired machines have less flotation and traction than crawler units, and less traction and higher flotation than a sanitary landfill compactor. Traction may become especially troublesome on wet or icy surfaces. In selecting rubber-tired equipment, the potential for tire punctures must be considered. Steel wheels are sometimes added to rubber-tired machines to increase traction and compaction while avoiding puncture problems.

Although relatively new, sanitary landfill compactors are being used increasingly. They are unique in being specifically designed for sanitary landfill application. Their steel wheels are equipped with load concentrators (teeth or lugs) of varying shape and configuration for more effective crushing of waste. These machines can provide high densities in the fill, thereby conserving landfill capacity.

Other equipment used at sanitary landfills include scrapers, water wagons, draglines, and graders.

All equipment should be capable of withstanding the heavy abuse of landfill work, which is generally much more rugged than earthwork. Rollover protection systems, seatbelts, fire extinguishers, and other safety equipment should be provided. Special precautions should be taken in equipment selection and operation to avoid the potential of engine overheating due to trash and dust accumulation. Undercarriages should be shielded to prevent damage by the solid waste. All moving parts should be enclosed to the greatest extent possible in order to avoid exposure to and accumulation of solid waste. Torque converters, gearing ratios, and differentials should be matched to the job to be done in order that the machine can work the desired slopes, travel effectively on solid waste, minimize spinout, and deliver maximum compaction.

The need for compaction of the waste and cover material has been emphasized. Good compaction is necessary to:

- Extend landfill life by placing as much solid waste in the available space as possible.
- Minimize the rate and extent of later settlement.
- Minimize leachate production and flow by eliminating voids and decreasing permeability.
- Reduce the possibility of fire by eliminating voids.
- Provide vector control.

Proper use of equipment is as important as wise selection of equipment for an effective, economical landfill operation. For example, in applying daily cover, the operator may readily achieve optimum soil density, but unless he takes care to back-drag his blade to smooth the surface, pockmarks left by his machine's treads or wheels can collect precipitation, leading to leachate generation, or allow vectors access to solid waste. Quality control of such operations requires care, observance, and training. Training materials are available from EPA, as well as some State solid waste management agencies and equipment manufacturers.

Provision must be made for standby equipment; the flow of incoming solid waste does not stop, but equipment does break down and require servicing. It is preferable to purchase an extra piece of equipment for use as a replacement during breakdowns and routine maintenance. It is likely that the extra machine will be found to contribute significantly to routine operations, as well as provide necessary backup. Arrangements can normally be made, however, with another public agency or private concern for the use of rental or replacement equipment on short notice.

Since efficiently operating equipment is essential, the machines must be cleaned and serviced regularly. Manufacturers' recommendations for servicing the machines *in sanitary landfill application* should be closely adhered to. As trash accumulation can be especially damaging, cleanliness deserves special attention. Protection against vandalism should also be considered.

Facilities

A maintenance and storage garage should be provided to protect sanitary landfilling equipment. The garage can also be used to store and protect handtools and equipment parts. The cost of a simple steel structure (a paved floor is desirable but not essential) to serve this purpose may be expected to range from $20,000 to $30,000.

Many landfills have found it most equitable, accurate, and easy to relate their fees and costs to the weight of incoming wastes. Weight of waste can also be used to indicate the rate of fill capacity utilization (for planning purposes) and as a control for collection operations. Costs of scale facilities vary considerably with size (which is usually related primarily to the size of incoming vehicles) and with the sophistication of the readout system (usually related to rate of incoming vehicles, since this determines required speed of scale operation, and type of records desired). Small, simple scale systems can be expected to cost about $11,000, including pit and excluding scale house. Larger, faster systems may cost $20,000 to $25,000, including pit and excluding scale house.

It is desirable to have an office at the site for recordkeeping (personnel and equipment) and billing; it might be combined with the garage and/or scale house. Sanitary facilities should be available for employees, and locker rooms and showers would be desirable. New or used mobile homes are often used for such purposes and can be obtained at relatively low cost.

Completed Sanitary Landfill

Information on the decomposition of waste in a sanitary landfill is limited. The rate of decomposition is primarily dependent on moisture content and may take place at a very slow rate. Paper has been found unchanged in landfills that have been completed for 15 to 25 years.

Decomposition of the wastes will result in the production of gases, principally methane and carbon dioxide plus small amounts of nitrogen, hydrogen, and hydrogen sulfide. The rate of gas production is likely to reach a peak within the first 2 years and then slowly taper off. However, due to the continuous placement of wastes in the fill over time, this peaking effect is not likely to be observable.

Methane causes the most concern because of its explosive character. Precautions should be taken to prevent the gas from concentrating in sewers or other structures located on or near the landfill. Methane will seek an easy exit from the fill. Thus, depending on site conditions and design, the methane may flow up vertically through the fill and disperse harmlessly in the atmosphere above, or it may flow laterally from the site to concentrate in adjacent structures such as buildings and pipes. Relatively simple and inexpensive techniques can be employed to vent the gas in a controlled manner on site and minimize lateral migration. Devices such as gravel-filled trenches and naturally vented stand pipes have been used successfully. In Winston-Salem, N.C., a forced ventilation system has been successfully demonstrated.

The potential for recovering, purifying, and marketing methane generated by sanitary landfills is being explored. Methane recovery offers a dual benefit in controlling gas migration, thereby eliminating a potential hazard, while harnessing an otherwise wasted energy source. Since January 1974, the city of Los Angeles has been successfully recovering methane from one of its landfills. The gas is extracted from a well and is used to run an internal combustion engine. The engine is used to produce 200 kilowatts of electrical power for about 350 residences. The NRG NuFuel Co. and the sanitation districts of Los Angeles County have also embarked on an effort to recover methane from a landfill. The gas extracted from a series of wells is being cleansed through a molecular sieve system for sale to a local gas utility. The cleansed gas is of pipeline quality and ready for direct insertion into a natural gas pipeline. The city of Mountain View, Calif., and the Pacific Gas & Electric Co. are cooperating with EPA in a pilot effort to define some of the parameters involved in gas extraction and to investigate gas marketing alternatives.

Completed landfills generally require maintenance because of uneven settlement. Maintenance consists primarily of regrading the surface to maintain good drainage and filling in small depressions. Where ponding of water in depressions is not prevented, seepage into the fill may result in pollution of ground or surface waters.

Several of the Los Angeles area sanitary landfills, 90 to 110 feet deep, have settled 2.5 to 5.5 feet in 3 years. Settlement is dependent on the depth of the fill, its composition, compaction of the material, moisture content, and other factors. Studies have indicated that approximately 90 percent of the ultimate settlement may occur in the first 5 years, with the final 10 percent occurring over a much longer period.

Although underground fires rarely occur in a completed landfill, the possibility does exist. All underground fires should be excavated and extinguished. The cell construction of a sanitary landfill helps to confine and restrict the spread of the fire, should one occur.

Completed landfills have been used for recreational purposes—parks, playgrounds, and golf courses. Parking, storage areas, and botanical gardens are other final uses. An early formal dedication of the sanitary landfill to its ultimate use as a recreational area may help to overcome local objections to future site locations.

Because of settlement and potential gas problems, construction of buildings on completed landfills should generally be avoided; in several locations, however, one-story, rambling buildings and airport runways for light aircraft have been constructed directly on completed sanitary landfills. In such cases, it is important for the designer to avoid concentrated foundation loading, which can result in uneven settlement and cracking of the structure. The designer also must provide the means to dissipate gas to the atmosphere and not into the structure. Spaces where methane could accumulate, such as basements, crawl spaces, and sanitary and storm sewers, should be avoided, or, if that is not possible, they should be ventilated. Competent engineering design is essential to insure continued safety and stability of the facility.

Multistory buildings can be built over completed landfills using steel and concrete pilings and special engineering design. Because of the complexity of design that must provide for differential settlement and control of gases, EPA does not recommend this use for a completed sanitary landfill or reclaimed dump site.

Regionalization

While sanitary landfilling is an essential service, small communities in particular may find the cost of maintaining an acceptable operation to be burdensome. By combining their resources and efforts into a joint or regional operation, two or more such communities can realize the greater economies of larger scale operations. Regionalization can aid in reducing the unit costs while providing a higher quality operation. For example, through regionalization communities can more readily finance superior equipment which would enable greater compaction and the resultant saving of landfill capacity. Regionalization might also justify the use of an extra machine, which would provide a backup capability while meeting the needs of the larger operation

CONCLUSIONS

Sanitary landfills are a necessary part of all solid waste management systems. In the short run, sanitary landfilling of unprocessed waste will continue to be the most frequently used and least expensive method of solid waste disposal, especially in areas where adequate land close to the source of waste is available at a reasonable price. Increasingly, resource recovery and volume reduction processes should be used in conjunction with sanitary landfilling of the residues and nonprocessable wastes to create a disposal system that is more conserving of land and other resources.

To avoid environmental damage, proper

procedures must be followed in landfill site selection, design, and operation. Pollution of surface and ground waters is the most serious of the potential problems.

Public education about sanitary landfills—what they are really like, why they are essential, how the sites will look when completed, etc.—is very important. The opposition of citizens to having a landfill in their vicinity is often based on insufficient information and wrong assumptions.

Through regionalization, small communities can afford better quality landfill operations at lower cost. Also, by agglomerating larger quantities of solid waste to achieve economies of scale, regionalization of sanitary landfilling could serve as the first step in implementing a resource recovery system.

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conservation, environmental effects decisions, collection, transport, processing, disposal criteria, cost, institutional factors, resource conservation.

REDUCING WASTE GENERATION

conservation, environmental effects decisions, collection, transport, processing, disposal criteria, cost, institutional factors, resource conservation.

Local government decision-makers have generally been involved in the two traditional areas of solid waste management—collection and disposal. As the cost and environmental concerns associated with disposal have increased, growing numbers of local governments have begun to include resource recovery within their solid waste management functions. While these three aspects of solid waste management deal with waste once it has been generated, they do not deal with the primary cause of solid waste management problems—the rapidly expanding quantity of waste being generated. In order to address this basic problem, a relatively new solid waste management concept called waste reduction, or source reduction, has evolved. The waste reduction concept involves policies that are designed to reduce the consumption of materials and products in order to reduce the generation of solid wastes.

Options in Waste Reduction

There are four technical options in reducing waste generation: product reuse, reduced material use in products, increased product lifetime, and decreased consumption of products.

The product reuse option is applicable to the broad and increasing category of consumer goods designed to be used once and thrown away. Reusable products could be substituted in many instances. A prime example of this option is the use of refillable beverage containers as a substitute for nonrefillable beverage containers.

The second option is to decrease the materials consumed in each product: for example, the elimination of excess packaging or the selection of smaller automobiles by consumers. This option could involve savings in energy as well as materials.

The increased product lifetime or durability option would involve the redesign of products for sturdier construction and or improved ease of maintenance. In general, the option would apply to so-called durable goods such as automobiles, tires, appliances, and furniture.

The fourth option—decreased consumption—would mainly involve a reduction in the per capita consumption of packaging or disposable products.

Implementation of Waste Reduction Activities

The implementation of any of these four waste reduction options would involve an alteration of the existing production and marketing structure of numerous companies, as well as a significant change in consumer habits. Since production and distribution systems are often national in scope, a local government is generally limited in its ability to implement a waste reduction program beyond its own procurement policies (e.g., the purchase of longer life radial tires for its vehicles—see chapter on Tires).

While in general little attention has been given to waste reduction at the local level, there has been one exception. In recent years, many communities and States across the nation have considered laws and ordinances that would encourage or require the use of returnable or refillable containers for beer and soft drinks. The most common of these is a requirement for mandatory deposits on beverage containers sold within the community or State. This type of legislation has been enacted by both the States of Oregon and Vermont and several local communities, including Bowie, Md.; Loudoun County, Va.; and Ann Arbor, Mich. The local laws, however, have not been implemented due to legal challenges.

The object of placing a deposit on beverage containers is to provide a monetary incentive for consumers to return the containers. The containers could then be refilled or, if they are not refillable, the metal or glass could be recycled. The economics of a deposit law generally favor a shift by beverage companies to refillable containers, and this shift has developed in both Oregon and Vermont. However, it is important to note that a mandatory deposit law does not ban nonrefillable containers. In fact, in both Oregon and Vermont, there are still beverages sold in nonrefillable containers (one-way glass and cans).

Benefits of Mandatory Deposit Legislation

The benefits that can be derived from a mandatory deposit system include not only reductions in the quantity of litter and solid waste, which are direct benefits for local governments, but also national benefits in terms of savings in materials and energy. In addition, beverages in refillable containers are generally cheaper to the consumer.

Highway Litter. Studies for EPA indicate that a mandatory deposit law is likely to result in decreases of 60 to 95 percent in the number of beverage containers discarded as litter. These calculations have been confirmed by data provided by both the Oregon and Vermont State Highway Departments which indicate at least a 65-percent reduction. The extent of litter reduction for a local community will depend on the percent of beverage containers that were already returnable and other local conditions.

Municipal Solid Waste. Beer and soft-drink containers constitute around 6 percent of municipal solid waste. A mandatory deposit system could reduce this amount by three-fourths—a decrease of 5 to 6 million tons per year nationwide. As with highway litter, the extent of solid waste reduction in each community will depend in part on the degree to which returnables are already being used and also on the efficiency of current solid waste management practices. The reduction in waste collection and disposal requirements for a community is not likely to be great, but this is probably true of any single waste reduction measure by itself.

Energy. It is clear that the reuse and recycling of containers would provide a significant savings in energy. A comparison of the different types of containers for the amounts of energy required to manufacture and use them in packaging the same volume of beverage has found that the refillable glass bottle, used 10 times, consumes 33 percent less energy than any one-way container now on the market. If 90 percent of aluminum cans are recycled, the energy savings would amount to 70 percent of that required to manufacture aluminum cans from virgin ore. Steel can recycling also results in an energy savings.

Consumer Savings. Beer and soft drinks sold in refillable containers are generally cheaper to the consumer than beverages in one-way bottles and cans. Savings as much as 3 to 5 cents per 12-ounce container have frequently been observed. However, the costs of handling and transporting returned containers may not be fully reflected in retail prices. These costs have been estimated to range from less than 1 to 2 cents per container; therefore, even with these costs added on, beverages in refillable containers should cost less to the consumer.

It should be pointed out that a rapid wide-scale shift to an all-refillable-bottle system would require considerable equipment changeover in the brewing and soft-drink industries and would result in costs that could be passed on to the consumer. If the transition to refillables takes place gradually over a period of years, the costs of rapid changeover would be avoided.

Disadvantages of Mandatory Deposit Legislation

The disadvantages that might result from the imposition of a deposit on beverage containers range from a potential decline in sales to a temporary industrial dislocation, consequent unemployment, and reduced tax revenues. These disadvantages would occur primarily in those communities where can or glass container manufacturing plants are located.

Sales. Beverage sales growth in both Oregon and Vermont declined somewhat after the enactment of the law. But it is not clear whether any real change in the long-term growth rate will occur as a result of mandatory deposit legislation.

Industrial Dislocations and Unemployment. If there was a major sudden shift by the beverage industry to refillable containers, one result would be the loss of employment in the manufacture of nonrefillable containers. To reduce this effect, beverage container legislation could be phased in gradually over a long period. This will not eliminate job losses, however.

A deposit law would also result in additional jobs being created in large retail outlets and in firms involved in the distribution and collection of the returnable containers. Estimates indicate that jobs lost are balanced by jobs gained, but the jobs gained tend to be lower paid.

Tax Revenues. A decline in tax revenues could result during the period of transition to a refillable system. This decline would be the result of corporate writeoffs for obsolete can lines and estimated losses in revenue from beer excise taxes.

Storage and Sanitation. A returnable beverage container system imposes additional storage requirements on retail stores and beverage distributors. There has been some concern about insect problems associated with the storage of containers containing beverage residues. On the other hand, refillable beverage containers have been used in many parts of the country for years without significant adverse public health effects. The problem can be minimized by proper enforcement of public health laws and sanitation codes and by frequent collection of containers.

Conflicts with Resource Recovery Systems

One of the issues of concern to local solid waste management authorities is whether reducing the generation of waste through mandatory deposit legislation would significantly affect the economics of resource recovery plants. In this regard it is important to note that approximately 80 percent of the municipal waste stream is organic material—paper, plastics, etc. This fraction should be the primary concern of a resource recovery facility, as it represents the bulk of the waste and provides the revenue ($5 to $15 per ton of waste processed) needed to make resource recovery competitive with other means of solid waste disposal.

Beer and soft-drink containers represent 35 to 45 percent of the glass in the municipal waste stream, 15 percent of the steel, and, where use of aluminum cans is substantial, 30 to 40 percent of the aluminum. Revenues that could be derived from the beverage container fraction of the waste stream amount to about $1 to $2 per ton of waste processed. When the costs of recovering these fractions are considered, the net revenue contribution is considerably less. Removal of the beverage container fraction through a mandatory deposit system would probably not cause a net revenue reduction in excess of $1 per ton of waste processed.

In light of the uncertainties of separating and marketing aluminum and glass from solid waste, beverage container legislation does not entail undue risk to the economics of resource recovery facilities.

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SPECIAL WASTES

Hazardous Wastes

Increasingly, environmental managers at all levels of government will be required to make decisions on how to cope with hazardous wastes. A brief and simple definition of a hazardous waste, for purposes of this document, would encompass those wastes which cannot or should not be handled or disposed of in the same manner as the community's normal residential solid waste load. The determination of whether a waste is hazardous would stem from a judgment that a significant potential exists for causing adverse public health or environmental impacts if the waste is handled, stored, transported, treated, or disposed of in the manner generally accepted for ordinary solid wastes.

General categories of hazardous waste are toxic chemical, flammable, radioactive, explosive, and biological. Such wastes can take the form of solids, sludges, liquids or gases. There is no "master list" of substances or compounds which are hazardous when placed onto or under the land. However, work done by and for the Office of Solid Waste Management Programs has identified a number of likely candidates (Table 43). Numerous wastes contain such compounds in quantities which render the waste unacceptable for normal methods of waste management.

THE PROBLEM

Hazardous wastes comprise only a small fraction of the nation's solid wastes. The environmental impact of hazardous wastes, however, is out of all proportion to the amounts because of the threats of severe health and environmental effects, both chronic and acute.

EPA estimates that the generation of nonradioactive hazardous waste is approximately 10 million tons per year. About 40 percent by weight of these wastes are inorganic materials, 60 percent organic. It is also estimated that 90 percent of hazardous waste exists in liquid or in semiliquid form.

At the present, there is no Federal legislation and very few State or local statutes regulating the disposal of hazardous waste on land. To fill this gap, EPA proposed the Hazardous Waste Management Act of 1973. Other bills of similar nature have also been introduced in the Congress recently. It is hoped that one of these bills will be enacted into law shortly.

As enforcement of the Clean Air Act, the Federal Water Pollution Control Act, and the "Ocean Dumping" Act closes off the air and the water as places in which to dispose of this waste, communities are going to feel the pressure of waste generators disposing of it in the only place left—the land. State and local governments, then, have to be aware of the problem of what hazardous wastes are and of what can and cannot be done with them without threatening the public health or insulting the environment.

The problem of environmental insults caused by improper land disposal of hazard-

TABLE 43

A SAMPLE LIST OF NONRADIOACTIVE HAZARDOUS COMPOUNDS*

Miscellaneous Inorganics
Ammonium chromate
Ammonium dichromate
Antimony pentafluoride
Antimony trifluoride
Arsenic trichloride
Arsenic trioxide
Cadmium (alloys)
Cadmium chloride
Cadmium cyanide
Cadmium nitrate
Cadmium oxide
Cadmium phosphate
Cadmium potassium cyanide
Cadmium (powdered)
Cadmium sulfate
Calcium arsenate
Calcium arsenite
Calcium cyanides
Chromic acid
Copper arsenate
Copper cyanides
Cyanide (ion)
Decaborane
Diborane
Hexaborane
Hydrazine
Hydrazine azide
Lead arsenate
Lead arsenite
Lead azide
Lead cyanide
Magnesium arsenite
Manganese arsenate
Mercuric chloride
Mercuric cyanide
Mercuric diammonium chloride
Mercuric nitrate
Mercuric sulfate
Mercury
Nickel carbonyl
Nickel cyanide
Pentaborane-9
Pentaborane-11
Perchloric acid (to 72%)
Phosgene (carbonyl chloride)
Potassium arsenite
Potassium chromate
Potassium cyanide
Potassium dichromate
Selenium
Silver azide
Silver cyanide
Sodium arsenate
Sodium arsenite
Sodium bichromate
Sodium chromate
Sodium cyanide
Sodium monofluoroacetate
Tetraborane
Thallium compounds
Zinc arsenate
Zinc arsenite
Zinc cyanide

Halogens and Interhalogens
Bromine pentafluoride
Chlorine
Chlorine pentafluoride
Chlorine trifluoride
Fluorine
Perchloryl fluoride

Miscellaneous Organics
Acrolein
Alkyl leads
Carcinogens (in general)
Chloropicrin
Copper acetylide
Copper chlorotetrazole
Cyanuric triazide
Diazodinitrophenol (DDNP)
Dimethyl sulfate
Dinitrobenzene
Dinitro cresols
Dinitrophenol
Dinitrotoluene
Dipentaerythritol hexanitrate (DPEHN)
GB (propoxy (2)-methylphosphoryl fluoride)
Gelatinized nitrocellulose (PNC)
Glycol dinitrate
Gold fulminate
Lead 2,4 dinitroresorcinate (LDNR)
Lead styphnate
Lewisite (2-chloroethenyl dichloroarsine)
Mannitol hexanitrate
Nitroaniline
Nitrocellulose
Nitrogen mustards (2,2',2" trichlorotriethylamine)
Nitroglycerin
Organic mercury compounds
Pentachlorophenol
Picric acid
Potassium dinitrobenzfuroxan (KDNBF)
Silver acetylide
Silver tetrazene
Tear gas (CN) (chloroacetophenone)
Tear gas (CS) (2-chlorobenzylidene malononitrile)
Tetrazene
VX (ethoxy-methyl phosphoryl N,N dipropoxy-(2-2), thiocholine)

Organic Halogen Compounds
Aldrin
Chlorinated aromatics
Chlordane
Copper acetoarsenite
  2,4-D (2,4-dichlorophenoxyacetic acid)
DDD
DDT
Demeton
Dieldrin
Endrin
Ethylene bromide
Fluorides (organic)
Guthion
Heptachlor
Lindane
Methyl bromide
Methyl chloride
Methyl parathion
Parathion
Polychlorinated-biphenyls (PCB)

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*U.S. ENVIRONMENTAL PROTECTION AGENCY. OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS. Disposal of hazardous wastes; report to Congress. Environmental Protection Publication SW-115. Washington, U.S. Government Printing Office, 1974. 110 p.

ous waste is widespread. EPA has on record a large number of such incidents, of which the following are representative samples:

- As a result of the burial of lead arsenate pesticide in Minnesota over 30 years ago, 13 people were hospitalized with arsenic poisoning in 1972. The poisonings were traced to ingestion of water from wells near the pesticide burial site.
- For several years, a large municipal

landfill in Delaware accepted both domestic and industrial wastes. In 1968, this disposal site had to be closed because chemical and biological contaminants had leached into the ground water. By 1974, this incident had affected the drinking water supply of over 40,000 residents; their water is presently provided by alternate sources. The cleanup costs are estimated to be up to $10 million.

- For 20 years, a laboratory in Iowa used a particular site for solid waste disposal. Over 250,000 cubic feet of arsenic-bearing wastes have been deposited there. Monitoring wells around the dump have established that there is over 175-ppm arsenic in the ground water. The U.S. Public Health Service drinking water standard for arsenic is 0.05 ppm. The dump site is located above a limestone bedrock aquifer from which 70 percent of the nearby city's residents obtain their drinking and crop irrigation water. Although there is no evidence that the drinking water is being affected, the potential for contamination cannot be underestimated.
- A Tennessee chemical company for a number of years was burying highly toxic pesticide wastes at a dump in shallow unlined trenches, at the rate of about a hundred 55-gallon steel drums per week. The containerized chlorinated hydrocarbon wastes gradually escaped into the subsurface environment, contaminating not only the ground water but also a nearby creek.

HAZARDOUS WASTE SOURCES

Sources of hazardous wastes are numerous and scattered throughout the country. Obvious ones are industry, certain Federal facilities (chiefly Department of Defense and nuclear energy facilities), agricultural activities (see below for recommended procedures for pesticide disposal), hospitals, and laboratories. It is estimated, however, that most hazardous wastes are generated by industrial sources.

Representative hazardous substances have been matched with industrial sources (Table 44). There are many other industrial hazardous waste generating sources, however.

According to a rough geographic distribution of industrial hazardous waste generation, about 70 percent of the country's industrial hazardous waste is generated in the Mid-Atlantic, Great Lakes, and Gulf Coast areas (Table 45).

TREATMENT AND DISPOSAL TECHNOLOGY

As concluded in EPA's 1973 report to Congress on hazardous waste disposal, technology for the proper treatment and disposal of hazardous waste is generally available. However, the lack of regulation and economic incentive discourages the use of environmentally acceptable treatment and land disposal methods.

Treatment processes for hazardous waste should perform the following functions: volume reduction, component separation, detoxification, materials recovery.

No single process can perform all these functions; a series of several processes are generally required for adequate treatment.

The general applicability of various treatment processes to types and forms of hazardous waste has been determined (Table 46). Many of these processes have been utilized previously for managing hazardous waste in industry and government. Several processes have capabilities for resource recovery. Selection of appropriate methods depends upon the type, form, and volume of the waste, and the relative economics of the processes.

WHAT TO DO WITH HAZARDOUS WASTES

Those wastes which cannot be disposed of safely in ordinary landfills should receive adequate treatment to render them nonhazardous prior to disposal. A small private hazardous waste management industry has emerged in the last decade, offering treatment and disposal services to generators. A preliminary compilation has been made of firms that are in the business of accepting hazardous waste for disposal; copies are available from OSWMP.

Requests for further information and technical assistance which relate to management of hazardous wastes should be direct-

TABLE 44

PRESENCE OF REPRESENTATIVE HAZARDOUS SUBSTANCES IN WASTE STREAMS OF SELECTED INDUSTRIES*

Industry	Hazardous substances										
	As	Cd	Chlorinated hydrocarbons†	Cr	Cu	Cyanides	Pb	Hg	Miscellaneous organics‡	Se	Zn
Mining and metallurgy	x	x		x	x	x	x	x		x	x
Paint and dye		x		x	x	x	x	x	x	x	
Pesticide	x		x			x	x	x	x		x
Electrical and electronic			x		x	x	x	x		x	
Printing and duplicating	x			x	x		x		x	x	
Electroplating and metal finishing		x		x	x	x					x
Chemical manufacturing			x	x	x			x	x		
Explosives	x				x		x	x	x		
Rubber and plastics			x			x		x	x		x
Battery		x					x	x			x
Pharmaceutical	x							x	x		
Textile				x	x				x		
Petroleum and coal	x		x				x				
Pulp and paper								x	x		
Leather				x					x		

*U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Disposal of hazardous wastes; report to Congress. Environmental Protection Publication SW-115. Washington, U.S. Government Printing Office, 1974. 110 p.

†Including polychlorinated biphenyls.

‡For example, acrolein, chloropicrin, dimethyl sulfate, dinitrobenzene, dinitrophenol, nitroaniline and pentachlorophenol.

TABLE 45

ESTIMATED INDUSTRIAL HAZARDOUS WASTE GENERATION BY BUREAU OF CENSUS REGION, 1970*

Region	Inorganics in aqueous		Organics in aqueous		Organics		Sludges†, slurries, solids		Total		
	Tons	Metric tons	Tons	Metric tons	Tons	Metric tons	Tons	Metric tons	Tons	Metric tons	Percent of total
New England	95,000	86,000	170,000	154,000	33,000	30,000	6,000	5,450	304,000	275,450	3.1
Mid Atlantic	1,000,000	907,200	1,100,000	1,000,000	105,000	90,800	55,000	50,000	2,260,000	2,048,000	22.9
East North Central	1,300,000	1,180,000	850,000	770,000	145,000	132,000	90,000	81,600	2,385,000	2,163,600	24.2
West North Central	65,000	59,000	260,000	236,000	49,500	45,000	18,500	16,800	393,000	356,800	4.0
South Atlantic	230,000	208,500	600,000	545,000	75,000	68,000	80,000	72,600	985,000	894,100	10.0
East South Central	90,000	81,700	385,000	350,000	44,000	40,000	9,500	8,600	528,500	480,300	5.3
West South Central	320,000	290,000	1,450,000	1,315,000	180,000	163,000	40,000	36,400	1,990,000	1,804,400	20.2
West (Pacific)	120,000	109,000	550,000	500,000	113,000	103,000	30,500	27,700	813,500	739,700	8.3
Mountain	125,000	113,500	5,000	4,540	50,000	45,400	11,500	10,400	191,500	173,840	1.9
Total	3,345,000	3,034,900	5,370,000	4,874,540	794,500	717,200	340,000	308,650	9,849,500	8,936,190	100.0

*BATTELLE MEMORIAL INSTITUTE. Program for the management of hazardous wastes. U.S. Environmental Protection Agency, 1974. 2v. (Distributed by National Technical Information Service, Springfield, Va., as PB-233630-PB-233 631.)

†Predominantly inorganic.

ed to OSWMP's Hazardous Waste Management Division or to the Solid Waste Management Representative in EPA's Regional Offices.

PESTICIDE DISPOSAL AND STORAGE

The potential seriousness of health and environmental hazards due to improper disposal and storage of pesticides and their containers became increasingly clear in the late 1960's as documented case studies accumulated. Expanding use of pesticides in the United States (an estimated 665 million pounds in 1968) and increasing numbers of spent containers requiring disposal (240 million in 1968, up 50 percent over the

TABLE 46

FUNCTIONS, APPLICABILITY, AND RESOURCE RECOVERY CAPABILITY OF CURRENTLY AVAILABLE HAZARDOUS WASTE TREATMENT AND DISPOSAL PROCESSES*

Process	Functions performed†	Types of waste‡	Forms of waste§	Resource recovery capability
Physical treatment				
Carbon sorption	VR,Se	1,3,4,5	L,G	Yes
Dialysis	VR,Se	1,2,3,4	L	Yes
Electrodialysis	VR,Se	1,2,3,4,6	L	Yes
Evaporation	VR,Se	1,2,5	L	Yes
Filtration	VR,Se	1,2,3,4,5	L,G	Yes
Flocculation settling	VR,Se	1,2,3,4,5	L	Yes
Reverse osmosis	VR,Se	1,2,4,6	L	Yes
Ammonia stripping	VR,Se	1,2,3,4	L	Yes
Chemical treatment				
Calcination	VR	1,2,5	L	
Ion exchange	VR,Se,De	1,2,3,4,5	L	Yes
Neutralization	De	1,2,3,4	L	Yes
Oxidation	De	1,2,3,4	L	
Precipitation	VR,Se	1,2,3,4,5	L	Yes
Reduction	De	1,2	L	
Thermal treatment				
Pyrolysis	VR,De	3,4,6	S,L,G	Yes
Incineration	De,Di	3,5,6,7,8	S,L,G	Yes
Biological treatment				
Activated sludges	De	3	L	No
Aerated lagoons	De	3	L	No
Waste stabilization ponds	De	3	L	No
Trickling filters	De	3	L	No
Disposal storage				
Deep-well injection	Di	1,2,3,4,6,7	L	No
Detonation	Di	6,8	S,L,G	No
Engineered storage	St	1,2,3,4,5,6,7,8	S,L,G	No
Land burial	Di	1,2,3,4,5,6,7,8	S,L	No
Ocean dumping	Di	1,2,3,4,7,8	S,L,G	No

*OTTINGER, R. S., et al. Recommended methods of reduction, neutralization, recovery or disposal of hazardous waste. U.S. Environmental Protection Agency, Aug. 1973. 16 v. (Distributed by National Technical Information Service, Springfield, Va., as PB-224 579-set.) ARTHUR D. LITTLE, INC. Alternatives to the management of hazardous wastes at national disposal sites. Environmental Protection Publication SW-46c. U.S. Environmental Protection Agency, 1973. 85 p. (Distributed by National Technical Information Service, Springfield, Va., as PB-225 164.) BATTELLE MEMORIAL INSTITUTE. Program for the management of hazardous wastes. U.S. Environmental Protection Agency, 1974. 2 v. (Distributed by National Technical Information Service, Springfield, Va., as PB-233 630–PB-233 631.)

†Functions: VR, volume reduction; Se, separation; De, detoxification; Di, disposal; and St, storage.

‡Waste types: 1, inorganic chemical without heavy metals; 2, inorganic chemical with heavy metals; 3, organic chemical without heavy metals; 4, organic chemical with heavy metals; 5, radiological; 6, biological; 7, flammable; and 8, explosive.

§Waste forms: S, solid; L, liquid; and G, gas.

number in 1963) indicated that these problems were increasing. Since little was known of the extent of the problem, or proper methods of disposal and storage, the Working Group on Pesticides, composed of representatives from several Federal departments, was asked to study the subject. More recently, in 1972, a Task Force on Excess Chemicals, with representation from all parts of the Environmental Protection Agency, was formed to study disposal problems relating to pesticides and other hazardous chemicals, and to recommend solutions. Using the knowledge and information gathered by these two groups, as well as by other Federal and State agencies and the private sector, EPA drew up recommended procedures for the disposal of pesticides. These recommended procedures were published in the *Federal Register* on May 1, 1974. Additional proposed regulations were published October 15, 1974.

The Procedures and Their Applicability

EPA's recommended procedures represent broadly based judgments regarding the disposal and storage requirements for pesticides and their containers that are necessary to protect the environment. Compliance is achievable using existing technology; however, facilities utilizing this technology are not readily available in all geographic areas.

The recommended disposal procedures apply to all pesticides and pesticide-related wastes, including those which are or may in the future be registered for general use or restricted use, or used under an experimental use permit. Additionally, they also apply to full containers, spent or used containers, and container residues. For packages and containers of pesticides intended for use in the home and garden or when single containers are to be disposed of on farms and ranches, the agency does not require that these disposal procedures be followed. Disposal of such items will have only minimal environmental impact, and it is preferable to dispose of them individually rather than concentrate them.

The storage criteria and procedures apply to pesticides, pesticide-related wastes, and contaminated containers which are classified as "highly toxic" (DANGER, POISON) or "moderately toxic" (WARNING) according to EPA's classification system for pesticides. The storage of pesticides and their containers which are in the mildly toxic category is judged not to present any undue hazards to public health or the environment and is therefore excluded from the procedures. The temporary storage of limited quantities of pesticides in the other categories, if undertaken at environmentally safe sites, is also excluded.

Disposal Methods

First preference in considering disposal techniques should be given to procedures designed to recover some useful value from excess pesticides and containers. Where large quantities are involved, one of the first recommendations is that the excess material should be used for the purpose originally intended, provided this use is legal. Another alternative is to return the material to the manufacturer for potential reuse or reprocessing. A third alternative may be the export of the material to countries where its use is desired and legal.

Should none of these alternatives be applicable, the ultimate disposal method should be determined by the type of hazardous material involved. Organic pesticides which do not contain mercury, lead, cadmium, arsenic, beryllium, selenium, or other toxic materials may be disposed of by incineration at temperatures which will ensure complete destruction. Maximum volume reduction is achieved by incineration, and the incinerator emissions can be treated so that only relatively innocuous products are emitted. Incineration is not, however, applicable to those organic pesticides which contain heavy metals such as mercury, lead, cadmium, or arsenic, nor is it applicable to most inorganic pesticides or metallo-organic pesticides which have not been treated for removal of heavy metals. Metallo-organic pesticides may be incinerated after treatment to remove the metal or metalloid atoms from the hydrocarbon structure.

If incineration is not applicable or available, disposal in specially designated landfills is suggested as an alternative. However, encapsulation prior to landfilling is recommended for certain materials such as those containing mercury, lead, cadmium, arsenic, beryllium, selenium, or other toxic materials and all inorganic compounds which may be highly mobile in the soil. Encapsulation of these will retard mobility and contain them within a small area which can be permanently marked and recorded for future reference.

Other disposal processes, such as soil injection, well injection, and chemical degradation, may be acceptable in certain areas for some materials. At present, such methods have been neither sufficiently described nor classified to suggest their general use. Regional Offices of EPA may be contacted for advice on specific areas.

Among the disposal procedures not acceptable are water/ocean dumping, open dumping, and open burning, except that open burning of small quantities of certain containers and open field burial of single containers on farms and ranches by the pesticide user may be acceptable in some areas.

EPA's recommended triple rinsing procedure will clean containers well enough so that insignificant contamination will occur when such containers are legally refilled with another pesticide belonging to the same chemical class. Triple rinsing also prepares containers for crushing or shredding and recycling as scrap. Provisions for this resource conservation step have been included in the recommended procedures; they specifically require that adequate rinsing be undertaken before reuse or recycling of containers.

Storage

Storage sites and facilities should be located and constructed to prevent escape of pesticides and contaminated materials into the environment. Provision for separate storage of different classifications of pesticides according to their chemical type, and for routine container inspection, should be considered. Special procedures should be followed in case of fires or explosions, and the fire and police officials should be provided with the names and telephone numbers of the persons responsible for each pesticide storage facility.

These recommended procedures are designed to alert all Federal, State, and local government agencies and private manufacturers, handlers, and users of pesticides to the need for proper disposal and storage of excess pesticides, pesticide containers, and pesticide-related wastes. EPA will conform to these recommended procedures in its own operations. State and local agencies are cautioned against adoption of recommended procedures as regulations without careful study of the environmental and economic factors applicable to their own situations, including the availability of disposal sites and facilities.

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Hospital Wastes

It has been estimated that approximately 10 pounds or more of solid waste per day per patient is generated in an acute-care medical facility. Of this amount, 2 to 4 percent can be defined as potentially hazardous. Such wastes include pathological and surgical waste, clinical and biological laboratory waste, animal carcasses, needles, syringes, patient-care items (such as linen, and personal and food service items), drugs, chemicals, and radioactive wastes. The following describes basic methods for dealing with these potentially hazardous medical wastes. (The special handling and disposal of radioactive material should be carried out in accordance with the appropriate State laws and Federal guidelines.)

Responsibilities

Each medical facility which generates hazardous waste should be responsible for:

- Providing proper storage, collection, processing, transport, and disposal of such wastes.
- Adopting written procedures for the above, and insuring that all personnel involved are cognizant of these procedures.
- Providing training to all personnel who will be involved in the handling and disposal of such wastes so that they can prevent, eliminate, or minimize the potential health and safety hazards.

At the same time, the communities in which these medical facilities are located are responsible for both the enactment and enforcement of regulations for dealing effectively with potentially hazardous wastes generated by these facilities.

Storage

Hospital waste should always be stored so as to prevent transmission of disease or causing of injuries.

Acceptable containers for hazardous hospital wastes include double-strength bags (either plastic or paper) which are impervious to moisture, double tied, and have a strength sufficient to resist ripping or tearing under normal use. If sharps (needles, blades, etc.) have been pulverized, melted, or otherwise processed so as to make them incapable of puncturing and cutting, they may also be disposed of in such containers. Containers for wastes containing sharps that have not been so treated should be punctureproof and should be taped closed so as to prevent escape of any material. All containers for storing or transporting hazardous wastes within the facility should be colored international orange and labeled "HAZARDOUS WASTE" in black letters at least 3 inches high.

Collection

When the storage containers of hazardous wastes are to be emptied into a processing or disposal system or simply into another container, precautions should be taken to avoid accidental contact with the waste. These precautions will depend upon the particular conditions but may include practices such as wearing impervious gloves and other protective clothing, providing for single-pass air ventilation and negative air pressure, and wearing appropriate respirators and face shields.

Hazardous wastes should be collected at least daily from the hospital for transport to a processing or disposal system or an interim storage site.

PROCESSING

Two processes which should be used when feasible are:

- Sterilizing of infectious wastes to destroy the disease transmission potential by methods such as autoclaving or chemical treatment.
- Grinding, melting, or pulverizing sharps to destroy their injury-producing potential.

Both of these processes should be carried out as soon as possible and with as little handling as possible.

In any processing, the dispersal of hazardous material in such forms as aerosols and liquids should be avoided through the use of proper coverings, seals, ventilation, etc., and personnel should be protected against contact with the material through the use of protective clothing and gear.

TRANSPORT

Hazardous waste materials should be packaged in appropriate containers, and such materials should not come in direct contact with any transport vehicle such as pushcarts, chutes, and trucks.

Reusable rigid containers, such as metal or plastic canisters, should be sanitized immediately after their contents are discharged. The following are approved methods for sanitizing such containers:

Heat: Exposure to heat of at least 180 F for a minimum of 15 seconds
Chemical rinse or immersion:
Hypochlorite—100 ppm for a minimum of 30 seconds
Chlorine/bromine combination—100 ppm for 30 seconds
Quaternary ammonia compounds (State-approved)—200 ppm for 30 seconds
Iodoforms, iodine—25 ppm for 30 seconds

DISPOSAL

The preferred disposal methods for hazardous hospital wastes are:

1. For liquids: Treatment in a sewage treatment plant capable of rendering the waste innocuous (secondary treatment, at least).
2. For combustible solids: Complete incineration followed by disposal of the ash in a sanitary landfill. If incineration is not feasible, then disposal should be by landfilling as set forth in "3" below.
3. For noncombustible solids: Burial in a sanitary landfill while packaged in containers which clearly identify them as hazardous wastes. Burial should take place immediately upon receipt at the landfill.

If operations such as shredding or baling occur at the sanitary landfill, they should *not* include loads of hazardous wastes associated with medical services.

CONCLUSIONS

Potentially hazardous waste from medical facilities, if handled properly, should not pose a threat to the health and safety of patients, staff, or the community. The responsibility for insuring proper handling rests both with the medical facility and the community.

The community should enact and enforce regulations in respect to the collection, processing, transport, and disposal of the potentially hazardous wastes, while the medical facility should insure that those wastes that are disposed of on-site, and those wastes that are transported and disposed of off-site, are treated in accordance with such regulations.

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Sewage Sludge

The ultimate disposition of sewage solids generated by municipal wastewater treatment plants is a perplexing problem of great concern to many wastewater treatment authorities. In past years, national emphasis has been placed on developing improved solids removal techniques and attaining higher air and water quality standards with little regard for the problems of disposal on land or in utilization of the vast quantities of sludge being generated.

Sewage sludges from municipal wastewater treatment plants vary considerably in their chemical, physical, and biological characteristics. This variability is largely a result of the types of wastewater treatment processes employed and the composition of the wastewaters entering the treatment plants. In many cases the decision to utilize or dispose of a particular sludge hinges upon its inherent characteristics; a complete and detailed analysis of the sludge is therefore highly recommended.

The Water Pollution Control Act Amendments of 1972 set deadlines for the implementation of secondary and best practicable treatment for municipal wastewater; in effect these deadlines require the upgrading of a large portion of the wastewater treatment plants throughout the country within the next 10 years. This upgrading of treatment levels will result in increased volumes of sewage sludges—in many cases, a doubling or tripling of current sludge generation rates. Such dramatic increases could have devastating effects unless they are planned for properly, with careful consideration given to the environmental, legal, economic, and social factors involved.

ALTERNATIVES

Utilization on Land

There are many ways of using sewage sludge on land as a soil conditioner and/or as a low grade fertilizer. Sludge can be applied to crop and forest land to maintain or restore depleted soil fertility levels and to reclaim abandoned strip-mined and marginal lands. Other potential uses of sewage sludge include erosion control projects and application on golf courses, cemeteries, highway median strips, parkland, and airports, and for turfgrass and ornamental shrub production, beautification programs, etc. Sewage solids may be applied in the liquid (2 to 8 percent solids), dewatered (18 to 30 percent solids), or dried state (40 to 100 percent solids). The two most common methods are liquid application and open dumping followed by plowing. Several less common methods are burial in trenches, ridge and furrow irrigation, spray irrigation, plow injection, and irrigation by flooding.

Of major importance when contemplating the use of sewage solids on food chain crops is the viability of pathogenic organisms and the uptake and accumulation of heavy metals in the edible portion of plants grown for human or animal consumption. Various methods are used to stabilize sludge which render it biologically safe. Several of the more common means of sludge stabilization are:

- Anaerobic digestion
- Aerobic digestion
- Heat treatment
- Lime stabilization
- Pasteurization
- Chlorine oxidation
- Composting
- Chemical fixation
- Long-term storage

Although properly stabilized, the possibility still exists for toxic metal accumulation in food chain crops. The metal elements of most importance in sludge are zinc, copper, cadmium, lead, and nickel. These are all potentially toxic to crops, and cadmium and lead may be hazardous if allowed to enter the food chain. The element that is of most concern from a public health viewpoint is cadmium. EPA's soon-to-be published Technical Bulletin on municipal sludge management practices for utilization and disposal of sewage sludge suggests application controls that will, if strictly followed, limit the accumulation of cadmium and other toxic metals in plants grown on sludge-amended soils.

A wide range of metals content has been observed in digested sludges taken from various communities; estimates of typical levels have been made (Table 47). In general, sludges with excessively high metals content should not be applied on land used to grow forage or food chain crops.

Sanitary Landfill

Sewage sludge can be disposed of in sanitary landfills with or without mixed municipal solid waste.

For disposal with mixed municipal solid waste, dewatered, digested sewage sludge is placed on the working face in a sanitary landfill and promptly covered with earth or municipal refuse. Opinion is divided as to the need for digestion and dewatering of sewage sludge prior to incorporation in a sanitary landfill.

While not widely practiced, it is possible to operate a sanitary landfill for sludge disposal alone. In such cases, sewage sludge would at a minimum require dewatering prior to placement in a landfill.

Thermal Processing

While incineration of sewage sludge or solid waste is often considered a disposal alternative, it is in fact merely a volume reduction technique since there remains a residue that requires disposal. Other forms of thermal processing include heat drying, wet air oxidation, pyrolysis, and use of sludge as supplementary fuel.

Sludge may be heat-dried prior to its utilization on land. This stabilization technique provides a high quality product (90-99 percent solids) that can be used as fertilizer.

TABLE 47

RANGE OF METAL CONTENT IN DIGESTED SEWAGE SLUDGES*
(Dry weight)

Analysis	Observed range (ppm)	Typical "domestic" sludge (ppm)
Zinc	500 to 50,000	2,000
Copper	250 to 17,000	1,000
Nickel	25 to 8,000	200
Cadmium	5 to 2,000 (0.1 to 40% of zinc)	15 (0.1% of zinc)
Boron	15 to 11,000	100
Lead	100 to 10,000	1,000
Mercury	1 to 100	10
Chromium	50 to 30,000	1,000

*MENZIES, J., AND R. CHANEY. Waste characteristics. *In* Factors involved in land application of agricultural and municipal wastes. Washington, U.S. Department of Agriculture, Agricultural Research Service, July 1974. 200 p.

either as is or fortified. Some degree of drying is required prior to incineration, pyrolysis, or use of the sludge as supplementary fuel.

Ocean Disposal

Sewage sludge has been deposited in the ocean by coastal cities, using either a pipeline or barges. The continued use of this disposal method is in doubt as a result of more stringent water pollution control laws.

Sludge Utilization and Disposal Costs

Until recent years, decision-making bodies have been able to avoid identification of the specific cost of sewage sludge handling and disposal by attaching such cost to the sewage treatment facility or sanitary landfill budget. As a result, there is a general lack of reliable comparative cost data on current and past disposal activities, and only approximate figures are currently available (Table 48). Actual cost will vary for each locale, depending upon such factors as volume of sludge to be handled, haul distances, local labor rates, cost of land, equipment cost, soil absorption capacity, etc.

Advantages and Disadvantages

Utilization on Land

The primary advantage of land applica-

TABLE 48

ESTIMATED TYPICAL COSTS OF SLUDGE DISPOSAL PROCESSES PER DRY TON, 1974

Methods	Cost per dry ton*
Dewatering:	
Vacuum filter	$31.00
Centrifuge	26.00
Sand beds	30.00
Land transport (5% solids):	
Tank truck	3.00/mile
Railroad	0.25/mile
Pipeline	1.55/mile
Land transport (30% solids):	
Dump truck	0.65/mile
Railroad	0.25/mile
Ocean transport (5% solids):	
Barge	0.20/mile
Outfall	0.60/mile
Ocean transport (30% solids): Barge	0.03/mile
Storage:	
30% (stockpile)	2.30
5% (lagoon)	14.00
Disposal (5% solids):	
Ocean disposal	—
Landfill	3.00
Land spreading	20.00
Disposal (30% solids):	
Ocean disposal	—
Landfill	3.00
Land spreading	10.00
Miscellaneous disposal methods:	
Incineration (total cost including dewatering)	50 to 85
Composting (total cost including dewatering)	Not accurately known at this time

*DERR, D. A., et al. Economic considerations for planning sewage sludge disposal systems. *In* A. Freiberger, *ed.* Pretreatment and Ultimate Disposal of Wastewater Solids. Proceedings, Research Symposium, Rutgers University, State University of New Jersey, May 21-22, 1974. [New York], U.S. Environmental Protection Agency, Region II. 476 p.

tion of sludge is that a relatively inexpensive soil conditioner and low-grade fertilizer is made of what would otherwise be mere waste. A secondary advantage is that requirements for other fertilizers are reduced, thus conserving natural resources used in their production.

The major disadvantage relates to the heavy metals and pathogenic organisms in sewage solids. In large quantities, such contaminants, especially heavy metals, can restrict the types of crops planted and can limit the ultimate use of the land. High concentrations of certain metals can also result in plant toxicity and reduced crop yields. Plant uptake of heavy metals, especially arsenic, cadmium, lead, mercury, and selenium, as well as the presence of pathogenic organisms on the surface of plants, can render the crops unfit for human or animal consumption.

There are two additional disadvantages of land application. The most obvious is the large amount of land that is generally required to utilize the sludge from a municipal wastewater treatment plant. Application rates of 10 to 25 dry tons of sewage solids per acre per year are typical; however, actual application rates can be determined only on a case-by-case basis depending upon the metals content of the sludge, soil type, climatological conditions, the type of crop or vegetation, application techniques, and whether the sludge is being applied in the liquid, dewatered, or dry state.

The other disadvantage is the potential that exists for ground and surface water pollution from infiltration and runoff of sludge contaminants, both biological and chemical. Proper selection, design, and operation of a sludge application site in accordance with EPA's forthcoming Technical Bulletin on municipal sludge management practices will minimize the potential for environmental degradation. A site-monitoring program should be established to fully assess the degree of environmental degradation, if any, taking place.

Sanitary Landfill

A sanitary landfill, if properly operated in accordance with EPA's guidelines on land disposal, will provide a safe and economically sound means of sludge disposal. Municipal solid waste layered with the sludge will help absorb excess moisture in the sludge. Operational problems such as bogging down of present equipment and site operator objections may be created as a result of incorporating sewage sludge into a sanitary landfill, however.

Critical attention must be devoted to site selection, engineering design, leachate and gas control monitoring systems, and operating plans in the development of any sanitary landfill receiving sewage sludge.

Very few advantages exist for operating a landfill solely for sludge disposal unless its proximity to the sewage treatment plant reduces transportation costs to near zero. The establishment of a landfill only for sludge results in unnecessary duplication of land disposal sites, and solves none of the potential problems in a combined sludge-solid waste sanitary landfill. In fact, operational problems may be aggravated by the absence of the absorptive and bearing capacities of mixed municipal refuse.

Thermal Processing

When sludge is incinerated or used in a pyrolysis unit or as supplementary boiler fuel, it must be dewatered. Dry sludge solids have a relatively high heat value, but considerable energy is required to drive off the water in the sludge and to bring the sludge to the combustion point. Since thermal processing alternatives require the use of substantial quantities of auxiliary fuels which may be very expensive and of limited availability, an economic analysis should be done and the energy balance calculated.

The potential for air pollution from thermal processing of sewage sludge is another serious disadvantage. Thermal processing facilities are extremely capital-intensive largely because of the pollution control equipment required.

Ocean Disposal

The main advantage of this alternative is the low overall cost to coastal cities, resulting from limited sludge treatment and dewatering requirements and cheap pipeline or barge transportation. The main disadvantage is the environmental and esthetic degradation of coastal waters which may result from this practice. In addition, the continued use of this disposal method as a viable solution to any city's sludge disposal dilemma is in doubt as a result of EPA regulations on ocean dumping and transportation for dumping purposes.

Conclusions

EPA (Office of Solid Waste Management Programs, Office of Research and Development, and Office of Water Programs), the Department of Agriculture, the Food and Drug Administration, and others are currently supporting research and demonstration efforts involving sewage sludge utilization and disposal.

The application of sewage sludge on land as a soil conditioner or fertilizer supplement, although commendable from a conservation point of view, could present environmental and health-related problems if it is not managed properly. Therefore it is strongly recommended that any sludge utilization system be designed and operated in accordance with the Technical Bulletin on municipal sludge management practices that will be issued shortly.

Furthermore, until such time as more information becomes available concerning the effects of disposing of liquid and unstabilized sewage sludges in a sanitary landfill, it is advisable to dispose of only properly digested or otherwise stabilized sewage sludge in accordance with recommended sanitary landfill practices. Liquid or undigested sludge disposal by sanitary landfilling may be acceptable if supported by a thorough environmental assessment.

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Tires

Used tires pose significant disposal problems for municipalities, industries, and private citizens. If incinerated in large quantities, tires produce unacceptable levels of particulates and sulfur emissions in the air. When landfilled, whole tires will resist compacting and burying and will rise to the surface, where they pose potential problems as breeding places for vectors and as fire hazards. The alternatives currently available in dealing with the tire disposal problem are in four categories.

Waste reduction through longer-life tires and retreading. These actions which reduce the generation of waste tires can be explored along with disposal and recovery alternatives which best suit a community's needs and capabilities.

Immediate disposal or recovery options. These disposal methods or tire recovery alternatives can be put into effect now, with no capital expenditure.

Short term disposal or recovery options. These alternatives require minor capital investment in equipment that is currently available or will be available in the near future.

Long term disposal or recovery options. These alternatives require significant capital investment and, in most cases, utilize technology which so far has been demonstrated only on a pilot scale.

ALTERNATIVES

Waste Reduction

The term "waste reduction," as used here, refers to a reduction in the consumption of products which results in a reduction in the generation of solid wastes. While waste reduction measures will not solve the tire disposal problem, they can decrease the number of tires being discarded. (About 200 million are being discarded each year.) There are two waste reduction options that are applicable to tires—increased lifetime and retreading.

The increased tire lifetime option can be implemented by government agencies and consumers through two actions: the purchase of more durable tires and improved tire maintenance. At the present time, the most durable tires available are radial tires with lifetimes approximating 40,000 miles. This is a considerable improvement in durability compared to belted bias and bias tires, which average approximately 30,000 miles and 20,000 miles, respectively.

The initial cost of more durable tires is generally higher; however, when the cost per mile of operation is considered, radial tires are generally more economical than less durable tires.

Regardless of the type of tire purchased, tire lifetime can be increased with proper maintenance. Assuring that tires are balanced and wheels are alined and careful monitoring of inflation pressure are the key elements of proper tire maintenance. The implementation of a tire maintenance program should be relatively easy for government agencies since these procedures could be accomplished in conjunction with regular vehicle maintenance. In addition to increasing tire lifetime, regular maintenance has a positive effect on retreading.

Forestalling tire disposal by retreading reduces the number of tires entering the solid waste system. The practice of retreading has been prevented from expanding, however, by two principal barriers, both of which can be affected by government decision-makers. These barriers are:

- Shortage of usable casings (tires suitable for retreading).
- Reservations about the performance of retreaded tires.

The number of usable casings could be increased through the institution and enforcement of tire standards as a part of periodic motor vehicle safety checks. A government agency can also generate higher quality casings from their own vehicles through the establishment of a regular tire maintenance program.

The second barrier to the growth of retreading—reservations concerning performance reliability—can be reduced as far as government agencies and other large users are concerned through the establishment of closed-loop retreading systems. A closed-loop system involves supplying casings from an agency's motor vehicle fleet to a retreader, who then retreads the usable casings and returns the retreads to the agency. This approach to retreading is a proven method to obtain quality retreaded tires. Commercial truck fleets have been using a closed-loop approach for many years with very good results.

The establishment of a closed loop system does not by itself insure quality tire performance from retreads. It does, however, involve two factors that should contribute to performance quality. First, the maintenance and use of the tires to be retreaded are controlled by the agency that will be receiving the retreads. Second, since a closed-loop system would involve an extended interaction between a retreader and an agency, a contract will probably be established which would give the agency control over the quality of the retreads received.

Identifying a qualified retreader with whom to establish a contract may be an obstacle. There are two methods of evaluating retreaded tires. The first would involve the testing by an independent tire examiner of a representative sample of retreaded tires from a supplier. In the second method the agency would place the retreaded tire samples on random fleet vehicles for actual road testing.

It is important to note that the quality of a retread is cost-dependent; that is, a high-quality retread will generally cost more than a lower quality retread. Therefore, if an agency elects to contract with a retreader that produces a quality product, the tires received will probably cost more than lower quality retreads.

In summary, the recommended approach to reducing the generation of tire waste is the initial purchase of more durable tires, preferably radial tires, the proper maintenance of these tires, and finally the retreading of usable casings through a closed-loop system.

Immediate Alternatives

There are several possible end uses for scrap tires that do not require capital expenditures. They involve reuse of the tires intact or sale to rubber reclaimers. Rubber tires, properly ballasted and secured in groups, apparently make satisfactory artificial reefs. Experimental reefs constructed of tires have been placed along the east coast by the Bureau of Sport Fisheries and Wildlife. Estimates of the cost of reefbuilding, *based on a free supply of tires* assembled at a dockside area, range from $0.50 to $4 per tire, depending on the type of reef constructed. Because of transportation costs, this option is feasible only in coastal areas.

Intact tires may also be used as crash barriers around obstructions near high-speed freeways, as bumpers for docks and towing vessels, and as retaining walls for soil erosion control. Costs for these applications will depend entirely on local conditions, and no generalized estimates are available at this time.

Another outlet is the reclaimed rubber industry, which uses scrap rubber in making compounds for manufacture of new tires and other rubber products. This industry consists of 12 facilities located primarily near tire manufacturers in Ohio and the Northwest. These facilities can draw tires from within a radius of 300 miles. Reclaiming plants are listed at the end of this chapter.

Short-Range Alternatives

These alternatives, landfilling and road-building, involve some capital expenditure—from $2,000 to $100,000—for either tire splitting or shredding equipment (Tables 49 and 50).

Generally less expensive than tire shredders, tire slicing/cutting machines can be obtained for between $2,000 and $4,000. These machines generally require one man to operate and can process from 60 to 300 tires per hour. Sliced tires have been successfully landfilled; some size reduction is effected, which is advantageous not only for landfilling but also for transportation. Most tire slicers are portable and so can be taken to suppliers of tires, making possible significant savings in transportation costs of the tires. At the present time, there are only limited uses for sliced tires.

TABLE 49

COSTS AND OPERATING PARAMETERS OF TIRE SLICERS AND SHREDDERS, 1974

Machine	Manufactured by	Price	Capacity (tires per hr) and tire type	Power requirements	Weight (lb)	Comments
Slicers:						
Ascot Tire Cutter	Parent Mfg. Co., Lewiston, Maine	$2,000-3,500	300, passenger and truck	110 V	1,500	Not rigged for road use
Branick	Branick Mfg., Fargo, N. Dak.	4,000	300, passenger and truck	220 V	1,000	Not rigged for road use
Shredders:						
Shred-Pax AZ-7	Teb Inc., Addison, Ill.	5,000	60, passenger	200 V 3-phase	800	Built in Germany, assembled in Illinois
AZ-15		8,500	60, passenger and light truck	200 V 3-phase	1,000	
AZ-20		19,000	300, passenger and truck	200 V 3-phase	*	
Tire Gator	Barclay/Noll Assoc., Burlingame, Calif.	75,000-90,000	1,000, passenger and truck	220/440 V 100 amp	*	1,000 tire/hr capacity would require 3 men
Tire-Gon	Automotive-Industrial Marketing Corporation, Portland, Oreg.	30,000	125, passenger and small truck	220 V 3-phase	3,000	Price includes trailer ($2,600), operating cost assumes 1,000 tire/day operation
Tire Hawg	Metropolitan Disposal Corporation, Portland, Oreg.	52,500	400, passenger and truck	440 V 3-phase	24,000	Weight includes trailer for road use

*Not available.

TABLE 50

BREAKDOWN OF TIRE-GON OPERATING COSTS AT 7.5¢ PER TIRE, 1974[*]

Item	Operating cost per month[†]
Labor	$600
Amortization	500
Maintenance	100
Power ($10/day)	200
Miscellaneous	80
Total	$1,480[‡]

[*] Manufacturer's data.

[†] No allowance has been made for transportation, dumping fee, revenue from sale of chips, or cost of capital.

[‡] Cost per tire is 7.5¢ given 1,000 tires processed per day with 20 days per month operation.

Portable tire shredders are relatively new to this country. Ranging in price from $5,000 to $100,000, several makes of tire shredders are currently available and more are in varying stages of development.

Shredders enable landfill operators to efficiently dispose of tires. Even more than slicers, they make tires cheaper to transport for either disposal or reuse. It appears that economics will generally favor bringing the shredder to the tires rather than bringing whole tires to the shredder. Some concentration of tires would be required, however, making the portable shredder most applicable for use at retreaders' installations and tire collection points.

There is increasing interest in making use of shredded tires as an additive to asphalt for roadbuilding and repairing. However, most proven asphalt-additive applications require rubber particles smaller (minus 16 plus 25 mesh) than present shredder output. It is also necessary to remove any steel belt or bead material from the rubber used for roadbuilding. Therefore, for most roadbuilding applications rubber reclaimers are relied on for the supplies of shredded tires.

Several governmental units are currently using rubber as an asphalt additive, including the city of Phoenix, Ariz., the New York State Department of Transportation, and the New York State Thruway System.

Information on the economics of operating tire slicers and shredders is sparse; costs will vary considerably with the number of tires processed and the availability of power-operated equipment to move and handle the tires. Most of the machines require one worker full time just to load or operate the machine. Additional labor is required to maintain higher rates of tire processing.

Long-Range Alternatives

There are several relatively capital-intensive uses for scrap tires that are currently under study by private and governmental organizations.

Destructive distillation and carbonization are two specific forms of pyrolysis—a controlled, oxygen-deficient heating process that decomposes organic substances. Tires are made up of carbon (83 percent), hydrogen (7 percent), and ash (6 percent), with trace quantities of nitrogen, oxygen, and sulfur. In pyrolysis, these constituents are yielded in the form of chemically complex oils and gases and a solid residue. The proportions of these yields vary according to the temperatures used in the process. The major product of high-temperature carbonization is carbon black, a major ingredient in synthetic rubber production. Destructive distillation, a lower temperature process, yields about 50 products—mainly gases but also oils (both light and heavy) and a dry high-carbon residue. This residue has a Btu value equivalent to coal but is relatively high in sulfur content (1.5 percent). The economics for all of these processes are marginal, but recent trends in the energy field may stimulate their development.

Hydrogenization is a process of chemical synthesis in which the addition of hydrogen (the element which is removed from oil to make synthetic rubber) converts scrap rubber to chemicals from which new rubber can be synthesized. It is estimated that much more development of this process will be required before it will be economically competitive with traditional synthetic rubber production. Current fossil fuel cost escalations may well speed up the time when this process too will become economically viable.

Energy can be recovered from tires by shredding them and using them as supplemental fuel in conventional coal-fired installations or as the sole fuel in specially designed furnaces for industrial applications. The Btu value of tires is equal to or greater than that of coal.

While even large cities may not generate enough tires to provide a continuous supply of supplemental fuel to a utility powerplant at this time, there would be enough for smaller coal-fired industrial boilers at certain locations. The General Motors Corp. is currently utilizing shredded tires as supplemental fuel at one of their plants.

A pilot installation in England has used tires as fuel in specially designed furnaces to generate steam. Because of the combustion properties of tires, such a furnace would probably operate at about 30 percent efficiency—about half that of a comparable coal-fired furnace. However, even at this low efficiency, the pilot operation in England consumes 700 tires per hour, generating 3,500 pounds of steam per hour, and effects savings of about $110 per day over the cost of coal (the cheapest available conventional fuel).

Goodyear has constructed and is operat

ing a cyclone furnace for whole-tire incineration and steam generation at its plant in Jackson, Mich.

It has been estimated that tire-fueled power could be competitive with gas- or oil-fueled power. The total estimated cost of generating power from tires is about $0.50 per million Btu. These costs include amortization of capital equipment and operating costs of storage, handling, preparation, and emissions control (50 percent higher than for coal) but *not* collection. Comparable costs for other fuel sources range between $0.60 per million Btu for gas and $0.75 for oil. These costs were calculated prior to 1973 price increases for petroleum products.

CONCLUSIONS

Although the disposal of discarded tires has proven to be a difficult solid waste problem in the past, new developments such as portable tire shredders now permit the sanitary landfilling of tires. In addition to this short-range solution to tire disposal, the potential currently exists for reducing the flow of tires into the solid waste stream through such means as increased consumption of longer-wearing tires instead of the less durable types, and retreading. Studies are now underway to expand present recovery markets and to develop long-range uses for discarded tires.

RECLAIMING PLANT LOCATIONS

A. Baker Manufacturing Company
South Bend, Indiana

Centrex Corporation
Findlay, Ohio

Eastern Rubber Reclaiming Company
Chester, Pennsylvania

Goodyear Tire and Rubber Company
Akron, Ohio

Laurie Rubber Reclaiming Company
New Brunswick, New Jersey

Midwest Rubber Reclaiming Company
East St. Louis, Illinois

Nearpara Rubber Company
Trenton, New Jersey

Uniroyal Chemical Division
Naugatuck, Connecticut

U.S. Rubber Reclaiming Company
Vicksburg, Mississippi

F. Perlman and Company
Memphis, Tennessee

Uniroyal Chemical Division
Ville d'Anjou, Quebec, Canada

Goodyear Tire and Rubber Company
Reclaim Division
Bowmanville, Ontario, Canada

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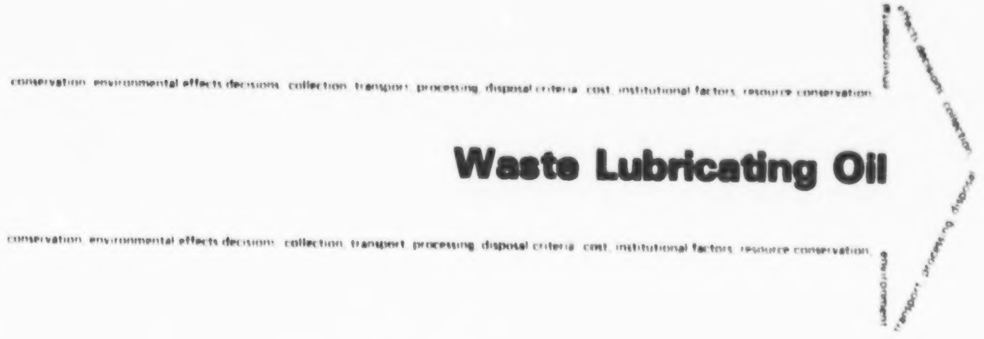
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Waste Lubricating Oil

Waste lubricating oil causes environmental problems when it is disposed of in unacceptable ways such as uncontrolled burning as a fuel, which can result in the emission of lead and other heavy metals; uncontrolled dumping on land, which can result in the contamination of ground water from leachate or contamination of waterways from runoff; and dumping in waterways, which can result in damage to fresh water and marine organisms.

Of the over 2 billion gallons of lubricating oils purchased annually in the United States, approximately 1 billion gallons are burned or otherwise lost in the process of lubrication; 600 million gallons of waste oil are generated from automotive use and 500 million gallons from industrial, aviation, and miscellaneous applications (Table 51).

Of the known uses of waste oil, burning is most common; it accounts for approximately 500 million gallons. Use as road oil and in asphalt consumes another 200 million gallons; 90 million gallons are re-refined into lube oil; and 300 million gallons are not accounted for. A significant portion of this latter quantity is probably burned as a fuel supplement during fuel shortages. The gen-

TABLE 51

CONSUMPTION OF LUBRICATION OILS, GENERATION OF WASTE OIL, AND USE OF WASTE OIL*
(In millions of gallons)

Consumption of lube oils	
Automotive	1,100
Industrial and aviation	700
Other (including government)	400
Total	2,200
Generation of waste lube oils	
Automotive	600
Industrial and aviation	400
Other	100
Total	1,100
Current uses of waste lube oils	
Fuel (treated and untreated)	490
Re-refined for use as lube oil	90
Road oil and asphalt	200
Fate unknown	340†
Total	1,100

*U.S. ENVIRONMENTAL PROTECTION AGENCY. Waste oil study: report to the Congress. Washington, U.S. Government Printing Office, Apr. 1974. 402 p.

†Includes 30 million gallons of re-refining wastes.

eration of waste oil appears to be increasing only slightly (1.3 percent annually) as longer periods between oil changes tend to offset the effect of increases in numbers of vehicles on the road.

COLLECTION

Waste oil is generally collected from service stations, garages, and commercial fleets by small, independent companies. There are approximately 1,500 of these collectors located in urban areas of the United States. They generally derive revenues from either a collection fee and or from the sale of waste oil. The oil is sold generally to processors who prepare it for use as a fuel, to re-refiners who make it reusable as lube oil, to manufacturers of road oil or asphalt, or directly to users of fuel. If the prices of petroleum products are low, then economic factors encourage collectors to dispose of their cargo in the most expedient manner—dumping.

In the less densely populated regions of the country, markets for waste oil are scarce and consequently there are very few waste oil collectors. As a result, the likelihood of waste oil dumping is increased. Municipal governments can take the lead in stimulating the recycling of waste oils and the reduction of oil dumping at a relatively small cost. The essential element is the assembling of sufficient quantities of waste oil to justify its collection. Either controls or incentives could be employed to concentrate the waste oils. Certain gas stations or converted storage tanks could be designated as collection points. Receptacles for collecting crankcase drainings can be fabricated from surplus gasoline cans or purchased from retail stores.

DISPOSITION

Use as a Fuel

The market for waste oil as a fuel, the major market for waste oil collectors, has two segments. The first is made up of waste oil processors who remove many of the contaminants in the waste oil prior to distributing it to users who mix it with conventional fuels. Some waste oil is distributed directly to users who mix the oil with conventional fuel without removing the contaminants. The contaminants will vary with the source of the waste oil and can include: lead, copper, barium, zinc, phosphorus, tin, and chromium.

The most serious of these contaminants appears to be the lead in automobile waste oil. If this oil is burned undiluted, significant emissions of lead can result. Although mixing with other fuel oils can dilute these lead emissions considerably, the burning of unprocessed waste oil is not recommended unless sophisticated emission control equipment is employed.

Re-refining

Another market for waste oil is the re-refining industry, which in 1972 processed 90 million gallons of waste oil into lube oil. Although this industry has experienced a decline (in 1960, 300 million gallons were processed), recent price levels for petroleum products have improved the economics of re-refining. Most of the problems facing the expansion of this industry center around questions regarding product quality. Reservations about the quality of re-refined lubricating oil led to Federal labeling requirements and purchasing restrictions. As a result, re-refined lube oil is often ranked only with low-grade virgin lube oils. The economic disadvantages that result are compounded by an unfavorable tax treatment (IRS ruling 68-108). Under the terms of this ruling, re-refiners are required to pay a nonrefundable tax of 6 cents per gallon on virgin oils which are blended with re-refined oil and sold for off-highway use. A similar tax on lube oil composed completely of virgin oil and used off highways is refundable.

A typical re-refining operation consists of dewatering, treatment with acid to remove additives and impurities, mixing with clay to remove low-boiling components, blending with virgin stocks to improve viscosity, and the use of additive packages to meet engine oil standards. The most serious environmental problem associated with re-refining is the disposal of the sludges and bottoms from the re-refining process. These wastes are generally highly acidic or contain high concentrations of heavy metals, primarily lead. These wastes can be satisfactorily disposed of in a properly managed landfill.

one which prevents leaching of acids and heavy metals into ground waters. The precautions recommended for the satisfactory landfilling of sludges and bottoms in EPA's *Petroleum Refining Point Source Category; Effluent Guidelines and Standards* (1974) include the following:

> In order to ensure long-term protection of the environment from harmful constituents, special consideration of disposal sites should be made. All landfill sites should be selected so as to prevent horizontal and vertical migration of these contaminants to ground or surface waters. In cases where geological considerations may not reasonably ensure this, adequate mechanical precautions (e.g., impervious liners) should be taken to ensure long-term protection of the environment. A program of routine periodic sampling and analysis of leachates is advisable. Where appropriate, the location of hazardous materials disposal sites should be permanently recorded in the appropriate office of legal jurisdiction.

Road Use

Use of waste oil for dust control on roads and in asphalt manufacture accounted for 200 million gallons of waste oil in 1972. Tests of the use of oil for dust control indicate that as much as 70 percent of the oil applied either migrates to the air on dust particles or onto adjoining lands and waterways through water runoff. The application of waste oil as a dust control measure should therefore be carefully controlled, taking into account such elements as the type of road surface, the amount of oil applied, and the type of vegetation near the road being oiled. When used in the manufacture of asphalt, waste oil can cause significant increases in emissions into the air. These emissions represent a potential hazard if they contain significant quantities of lead or other heavy metals.

Land Spreading

Many petroleum refineries currently dispose of oily wastes by a technique known as land spreading. If deep, fine-textured soils are selected for this practice, then limited amounts of oil will adhere to the soil and ground water contamination can be avoided. However, indiscriminate dumping of oil on coarse, porous, or shallow soils is likely to result in water pollution. Although under certain carefully controlled conditions land spreading may be environmentally acceptable, it represents an extremely inefficient utilization of a nonrenewable resource.

PROCUREMENT OF RE-REFINED LUBRICATING PRODUCTS

Cities may want to consider the use of re-refined lubricating products in city-owned vehicles. This may result in savings as re-refined products are usually available at lower prices than comparable virgin products. However, it is important that cities insure that the products will perform as intended. One or more of the following precautions should be taken:

1. Perform independent laboratory analysis of the re-refiner's base stocks and level of additives.
2. Obtain a certification of product performance by an additive manufacturer.
3. Seek testimonials from current local customers using re-refined products for similar lubricating applications.
4. Require certification from the re-refiner that his product meets or exceeds engine manufacturers' specifications.
5. Perform periodic laboratory monitoring of products to detect changes in processing or additive content.

At least one major city, San Diego, is currently using re-refined lubricating products in city-owned vehicles. The city has been using re-refined products since 1974; no loss in engine performance has been detected thus far. EPA will be working with the city to fully evaluate the performance of re-refined products after 2 years of use. Upon completion of the tests, EPA will make available the results to others wishing to explore the use of these products.

CONCLUSIONS

Cities and municipalities should identify quantities and sources of waste oil generation. Collectors of waste oil should also be identified as well as forms of disposition of the waste oil.

All methods of disposition of waste oil

TABLE 52

USES FOR WASTE LUBRICATION OIL*

Uses	Provisos
Re-refining for use as lube oil	Re-refining sludges and bottoms should be properly disposed of. Follow acceptable procedures for landfilling of sludges and bottoms.
Processing for use as fuel oil	Processor removes heavy metal contaminants (primarily lead) and processing bottoms are disposed of in an acceptable manner.
Burning untreated as a fuel	User employs sophisticated emission control equipment (including baghouses) to remove preventable lead emissions.
Spreading on roads for dust control	Oil use governed by ability of road surface to absorb oil, limiting significant migration on dust particles and oil runoff with water to adjacent areas.
Mixing with asphalt in road construction and repair	Process residuals containing concentrations of heavy metals should be disposed of in an acceptable manner.

*U.S. ENVIRONMENTAL PROTECTION AGENCY. Waste oil study; report to the Congress. Washington, U.S. Government Printing Office, Apr. 1974. 402 p.

should be controlled to avoid unfavorable environmental effects (Table 52).

Cities can stimulate the collection of waste oil by providing and/or promoting facilities at which waste oil will be accepted.

Cities should consider the use of re-refined lubricating products in city-owned vehicles if adequate precautions regarding product quality are observed.

In order to control the collection and disposition of waste oil, communities should issue appropriate laws and ordinances that—

- make dumping into watercourses illegal.
- require a permit for the operation of a facility to process or dispose of waste oil.
- require a permit for the collection of waste oil.
- require that all major waste oil generators contract with certified collectors for the hauling of this product.

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APPENDICES

Appendix A
Residential Collection Management Tools

This appendix describes three tools that EPA has developed to help managers evaluate and improve the efficiency of their residential collection systems. These tools are:

Collection Management Information System (COLMIS)
Route balancing procedure
Heuristic routing technique

MANAGEMENT INFORMATION SYSTEMS

The basis of effective management and decision-making is reliable information on the system being managed. While lack of information can lead to loss of control, good information can serve as the basis for improvements and cost savings.

In solid waste management, definitive information is needed on the operational aspects of collection and the costs involved in providing this service. This information should provide the answers to such key questions as:

- What are the actual collection costs per home and per ton?
- How much waste is collected per home per week? How does this vary seasonally?
- How many homes are collected per crew per collection hour?
- Which are the most productive and least productive crews?
- How are productivity and costs affected by different collection frequencies, crew sizes, equipment types, and storage devices?
- How effectively are the equipment capacities being utilized? What is their density capability?
- How many homes constitute a load for different generation rates?
- What are equipment operating costs? When should equipment be replaced?

A good method of obtaining the required information is through the use of a computerized reporting system. One such system is COLMIS, Collection Management Information System, available from EPA at no charge. This system generates reports with different levels of detail for the various levels of management.

There are three basic reports which the COLMIS system generates on a weekly basis. Each of these reports includes daily data for each route plus a weekly average and a year-to-date average. The following lists the categories of data included in the reports.

Route Information Report

- Motor pool to route—time and miles per day
- Collection operation—time and miles per day
- Transport operation—time and miles per day

- Total time to route, collect and transport—hours
- Downtime—hours
- Lunchtime—hours
- Weight per day—pounds and tons

Collection Information Report

- Homes served per collection day
- Weight in pounds per collection day
- Persons served per collection day
- Generation rate per person per day—pounds
- Collection time per home—minutes
- Collection time per 100 pounds—minutes
- Collection time as percent of total time worked
- Total time worked as percent of standard time
- Loads per day to incinerator, landfill, or transfer station
- Weight per cubic yard of first load—pounds

Collection Cost Information in Dollars

- Cost from motor pool to route
- Cost of collection operation
- Cost of transport operation
- Equipment costs
- Manpower costs
- Total costs
- Costs of manpower during equipment down periods
- Incentive costs
- Overtime costs
- Cost per ton
- Cost per home—per week, per year

While serving as a creditable record of operations and costs, these reports are a valuable planning tool. Information from these reports can be used to evaluate the present system and to design new systems. They provide the specific data needed to determine a "fair day's work" for each crew, truck and crew requirements for the entire city, boundaries for daily routes and districts, and costs of operation. They can also aid in determining the useful life for equipment and thus help in planning a capital replacement program.

Regional Application

COLMIS can be useful in solid waste management in cities of almost every size. It can also be used effectively by groups of neighboring communities, such as members of a disposal authority, council of governments, or planning council. Such a regional approach gives additional benefits to each community: It provides a standard data base so that each community can compare its system with those of its neighbors. This standard base will facilitate the exchange of ideas among managers. Regional sharing of information makes it possible for managers to see the productivity of other types of collection systems and to assess more easily the impact of system changes which they may consider introducing. The regional approach can also lower data-processing costs.

Regional systems are most easily implemented when there is a central agency that can coordinate the effort. The agency's function would include collection of the background data needed to start the COLMIS system, receiving the daily forms from the communities, providing or contracting for computer services, and distribution of the COLMIS reports to the communities. The communities may also want the central agency to function as a consultant to help them interpret the COLMIS reports and to advise them in improving their collection systems.

Cost Effectiveness

Effective use of this type of analysis can lead to significant results. Fourteen of the 35 communities in which the COLMIS program has been installed are in the same regional authority in Michigan, the Southeast Oakland County Incinerator Authority, which serves a population of 360,000. Management information from COLMIS and assistance from the authority and EPA in routing and evaluating crew sizes, equipment types, and collection methodologies have enabled these communities to maintain the same level of service (once-per-week, curbside) while cutting direct collection costs by 16.7 percent (within a 6-month period) and demonstrating a potential reduction of another 21 percent if all the communities and routes are converted to the most efficient system which has been identified.

The cost-effectiveness of COLMIS can be

seen by comparing its costs to the savings achieved. The total computer cost, including keypunching, for processing the data for this 360,000 population is $5,200 per year, a 1.4 cents per person per year investment with a resultant savings of 73 cents per person per year.

ROUTE BALANCING

Route balancing is the process of determining the optimum number of services that constitute a fair day's work and dividing the collection task among the crews so that all have equal workloads. Route balancing can have any of the following objectives: (1) to estimate the number of men and trucks required to collect waste in a new or revised solid waste system, (2) to aid in developing or evaluating a bid price for a collection contract, (3) to aid in evaluating the performance of the collection crews, as a whole or individually, (4) to establish a work standard to be used in a task system, in which the crews may go home when their predetermined tasks are completed for the day, or in a wage incentive system, in which the crews are rewarded by financial bonuses for any increases in productivity over a prescribed standard or over a previous period, or (5) to balance or equalize the workloads among collection crews.

Route balancing is necessary if a new collection system is being instituted, or a major change in the present system, e.g., backyard to curbside collection, is going to take place, or if a collection contract is up for bid. Route balancing should also be conducted if crew performances have never been evaluated or need reevaluation, if the present routes are not balanced, or if the present routes do not provide a fair day's work for the crews.

A fair day's work is determined and routes are balanced by analyzing each component of time in the collection day, that is, how the crew spends its time.

Adding the component times of a collection day results in an equation for the total time in the workday (Y):

$$Y = a + b + n(c_1 + c_2 + d) - c_1 + e + f + g$$

where

a = time from garage to route
b = total collection time on route
c_1 = time from route to disposal site
c_2 = time from disposal site to route
d = time at disposal site
e = time from disposal site to garage
f = time for official breaks
g = slack time (lost time due to breakdowns and other delays, lunchtime, and incentive time)
n = number of loads

This equation is the basis of the analysis for a fair day's work and route balancing.

The data required for this analysis are: (1) time and distance data related to the components of the collection day, (2) the number of services by type and where they are located, (3) the amount of waste generated per service, including seasonal variations, and (4) basic equipment and labor costs.

One method for gathering this data is by using COLMIS as already discussed. Values for each time variable are readily obtainable for any existing system from the COLMIS reports or other records. Values for each of these time elements for each route may be compared to ascertain their reasonableness.

In designing a new collection system it is necessary to determine the appropriate number of services per crew per day, which tells how many trucks and men are required. The steps required are:

(1) Add variables a, e, f, and g, and subtract c_1. These variables are readily obtainable from the existing system.
(2) Add variables $c_1 + c_2 + d$ (round trip haul and dump time for one load) for specific route areas, which are also available from the existing system.
(3) Select the equipment type and size and crew size.
(4) Determine the number of services per load (N).

$$N = \frac{\left(\begin{array}{c}\text{Vehicle capacity}\\ \text{(cu yd)}\end{array}\right)\left(\begin{array}{c}\text{Waste density capability}\\ \text{(lb/cu yd)}\end{array}\right)}{\text{Generation rate (lb/home/wk)}}$$

(5) Determine the collection time per service through obtaining statistics (such as COLMIS data) from other communities which have similar systems and good labor productivity or by conducting an experiment on one of the existing routes.

(6) Determine how much time it takes to collect one load by multiplying the results of steps 4 and 5.

(7) Set the total day equal to the number of hours the collectors are to work, e.g., 8 hours.

(8) Add the times from steps 1, 2, and 6 and compare to step 7.

(9) Add steps 2 and 6 to step 8 and compare again to step 7. Repeat this until the total time is close to the total day value selected in step 7.

(10) Calculate the number of trucks required to serve the community:

$$\text{Trucks required} = \frac{\left(\text{Total No. services}\right)\left(\text{Collection frequency per week}\right)}{\left(\text{Services per truck per day}\right)\left(\text{No. workdays per week}\right)}$$

In this equation, the value of services per truck per day is a function of frequency of collection and point of collection (curb or backyard) and is the value calculated in step 9 based on on route versus transport time.

(11) Calculate the cost of a crew and truck.

Vehicle cost = depreciation
+ maintenance
+ consumables
+ overhead
+ license fees and insurance

Labor cost = salary of driver
+ salary of collector(s)
+ fringe benefits
+ indirect labor
+ supplies (e.g., gloves)
+ administrative overhead

Total cost = vehicle cost and labor cost

(12) Multiply cost per crew by the number of crews needed to get total system cost.

(13) Divide cost per vehicle by number of customers the truck can serve per week to find the cost per customer.

(14) Evaluate the effects of peak and low generation periods by performing the calculations for steps 1 through 6 using data from these periods.

(15) Repeat steps 1 through 7 for any other system that could provide the service. Some figures such as time per stop and vehicle costs may have to be obtained from other sources.

(16) Comparison of total cost and cost per customer for each system examined helps give a picture of relative degrees of efficiency. The choice may be to pick a system different from the present one. Or it may be shown that level-of-service or other policies should be reconsidered.

HEURISTIC ROUTING

Routing is the process of determining the path or route the collection vehicle is to follow as it collects waste from each service in a specific area. The objective is to minimize the noncollection distance (e.g., streets with no services or repeat streets) and delays due to U-turns, rush hour traffic, left turns, etc., for each collection vehicle.

Once the number of services for each route has been determined through route balancing analysis, routing can be performed. All the data required for routing can be recorded on community maps. The data include (1) the number of each type of service on each side of each street segment, (2) all one-way, dead-end, and heavily traveled streets, (3) corner-lot residents, and (4) streets that should be collected one side at a time.

EPA has developed a "heuristic" routing technique that can be applied by the collection system supervisory personnel without the use of computers or a consultant. The heuristic technique is based on applying some common sense rules of thumb in conjunction with specific routing patterns. The major rules of thumb are:

(1) Routes should not be fragmented or overlapping. Each route should be compact, consisting of street segments clustered in the same geographical area.

(2) Total collection plus haul time should be reasonably constant for each route in the community, i.e., workloads should be equal.

(3) The collection route should be started as close to the garage or motor pool as possible, taking into account heavily

traveled streets, route elevations, and possible patterns (see rules 4, 6, and 9).

(4) Heavily traveled streets should not be collected during rush hours.

(5) Services on dead-end streets can be considered as services on the street segment that they intersect since they can only be collected by passing down that street segment. To keep left turns at a minimum, collect the dead-end streets when they are to the right of the truck. They must be collected by walking down, backing down, or making a U-turn.

(6) When practical, steep hills should be collected on both sides of the street while the vehicle is moving downhill for safety, ease, and speed of collection, to reduce vehicle wear, and to conserve gas and oil. Higher elevations should be at the start of the route.

(7) For collection from one side of the street at a time, it is generally best to route with many clockwise turns around blocks and to collect waste when it is to the right of the vehicle.

(8) For collection from both sides of the street at the same time, it is generally best to route with long straight paths across the grid before looping clockwise.

(9) For specific block configurations within the route, routing patterns should be applied. (Specific routing patterns are available in the third and fourth publications listed below.)

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Appendix B
Collection Costs and Productivity

The cost and productivity tradeoffs faced by a city official or private contractor in operating a collection system are complex. Preceding papers have attempted to deal with subsets of these tradeoffs on an issue-by-issue basis, e.g., point of pickup comparisons can be made by holding all other variables constant and comparing the difference in cost between curbside and backyard collection. This appendix discusses overall collection cost factors, ranges of cost elements that appear to be reasonable, and the results of a study of costs and productivity of systems in 11 cities.

OVERALL COLLECTION COST FACTORS

There are eight key cost factors which should be examined for every collection operation.

Equipment

- Depreciated vehicle procurement cost
- Maintenance cost
- Consumable items
- Miscellaneous costs (e.g., insurance, license fees)

Labor

- Wages
- Fringe benefits

Overhead

- Management and administrative overhead
- Office and garage rental, utilities, and supplies, etc.

While it is difficult to make national estimates of these costs because of wide variations, broad ranges can be determined.

RANGES OF COST ELEMENTS

The typical annual costs for two- and three-man crews working with a 20-cubic-yard rear-loading vehicle have been estimated (Table 53).

Clearly, labor costs (including fringe benefits) account for the largest portion of total collection costs (48 to 55 percent). Using these and similar sample figures, collection operating officials can begin to identify deviations in their costs. Many of the standard factors, e.g., 18 percent for fringe benefits or 13 percent for management and administrative overhead, vary from city to city. Each city should derive its own numbers for these cost factors where possible.

Collection cost per ton and collection cost per service per year are other useful indexes because they relate costs to a productivity measure. Since cost per ton is the ratio normally used to express processing and disposal costs, collection cost per ton is useful in calculating the overall collection, processing, and disposal costs for a system. Cost or price per ton is also the measure

TABLE 53

TYPICAL YEARLY COLLECTION COSTS FOR 2- AND 3-MAN CREWS INCLUDING VEHICLE, 1975

Cost elements	2-man crew	3-man crew
Depreciated vehicle procurement cost*	$6,900	$6,900
Maintenance cost	1,000	1,000
Consumable items		
Fuel (6,065 gallons × $0.36)	2,180	2,180
Oil	180	180
Tires	1,680	1,680
Miscellaneous (insurance, fees)	1,000	1,000
Labor, including 20 percent fringes		
Driver ($5.00/hour)	12,480	12,480
Helper(s) ($4.50/hour)	11,232	22,464
Management and administrative overhead (30 percent of direct labor)	7,114	10,483
Total	$43,766	$58,367

*Straight line depreciation over 5 years at 6 percent interest. Vehicle is 20 cubic yard rear loader.

used for quoting the market value of reclaimed materials. Thus, the additional collection and processing costs per ton for a reclamation program can be readily compared to the revenues per ton from recycled materials and savings per ton in disposal. The cost per service per year ratio is a more meaningful figure to the homeowner since it tells him how much solid waste collection and disposal are costing him.

COST AND PRODUCTIVITY STUDY

Cost constitutes only half of the decision-making factors in evaluating a collection system. Productivity is the other side of the ledger, and an operating manager must attempt to balance the two sides.

Several indexes have been developed to show system productivity. Some of these are services/day/truck, services/man-hour, tons/day/truck, and tons/man-hour. As can be seen from these measures, crew size, tonnage collected, and time to collect are elements in achieving high productivity.

Results are available of a study comparing the productivity and costs of nine curbside and two backyard systems with different equipment types and crew sizes (Table 54). Overall, three-man crews proved to have a significantly higher cost. Both the cost/home/year figures and cost/ton figures should be examined since the average weight per service directly affects the number of services a crew can collect.

The data for the study was obtained from the EPA Data Acquisition and Analysis Program (DAAP) and from time-and-motion study information from systems in various parts of the country. The DAAP is similar to COLMIS (see Appendix A). The figures shown in Table 54 represent the average values for four different routes for each system. The DAAP information represents data collected each working day for each route for a full year. The time-and-motion study information represents data collected for 1 day for each crew for each quarter of the year. The first column presents data from Utah; the second, from California; the third, Michigan; the fourth, Illinois; the fifth, Rhode Island; the sixth, Illinois; the seventh and eighth, Arizona; the ninth, Florida; the tenth, California; and the eleventh, Wisconsin.

The first section of the table describes the systems being evaluated. The next section shows on a percentage basis how the total man-hours of the crew are distributed among activities. Next is a summary of how much of the crew time is spent on productive activities—those activities which must be performed to pick up the waste and haul it away. Transport, for example, is productive time for the driver but not for the collectors, which penalizes the larger crew sizes. Collecting, driving, riding, walking, and compaction times are considered as productive times. Waiting and other time are nonproductive.

Since many variables affect crew perform

TABLE 54

PRODUCTIVITY AND COST ANALYSIS FOR RESIDENTIAL COLLECTION SYSTEMS, 1973*

	Collection policies and methodologies										
	Curb/alley systems									Backyard systems	
System number	1	2	3	4	5	6	7	8	9	10	11
Collections per week	1	1	1	1	1	1	2	2	2	1	1
Crew size	1	1	2	2	3	3	1	2	3	2	[illegible]
Incentive system	Task	8 hr	Task	8 hr	Task	8 hr	Task	Task	Task	Task	8 hr
Collection patterns	One side	One side	One side	One side	Both sides	Both sides	One side	One side	Both sides	Tote barrel	Tote barrel
Vehicle size (cu yd) and type†	25 SL	25 SL	20 RL	25 RL	20 RL	25 RL	33 SL	8 SL	20 RL	20 RL	13 RL
Percent of total crew time spent on various collection activities											
Transport	34.8	32.2	31.5	30.2	24.2	35.4	22.6	27.2	30.0	18.5	20.6
On route:											
Driving	17.3	13.5	8.9	12.2	5.8	3.1	24.7	10.0	7.3	‡	‡
Riding, walking§	0.0	0.0	7.8	11.6	11.8	5.8	0.2	18.1	14.7	‡	‡
Collecting	45.8	51.5	30.6	19.5	35.7	30.2	50.1	27.8	29.1	81.5	79.4
Waiting (including compaction)‖	0.8	1.8	20.8	26.8	22.2	17.3	1.1	6.5	18.5	‡	‡
Other‖	0.7	1.0	0.4	0.2	0.3	0.4	1.3	10.4	[illegible]	‡	‡
Total productive time	98.5	97.2	63.0	58.3	61.3	58.7	97.6	69.5	61.0	‡	‡
Route characteristics (daily averages)											
Pounds per home per collection	46.2	31.0	49.1	40.5	62.2	64.9	98.2	24.4	33.1	33.9	51.1
Number of bags per home per collection	1.5	1.5	2.0	4.6	3.6	1.5	0.9	0.5	1.2	0.0	1.4
Number of cans per home per collection	2.5	2.2	1.5	0.4	1.8	2.7	1.6	2.9	1.1	2.2	2.4
Number of miscellaneous items per home per collection	0.7	1.7	0.7	0.5	3.0	1.7	0.5	0.7	0.4	0.0	0.0
Collection miles per day	10.2	6.1	10.5	13.1	10.0	4.5	2.7	20.5	10.4	6.9	6.6
Transport miles per day	46.3	18.8	33.6	29.9	14.3	30.4	23.3	12.0	13.3	8.5	17.6
Collection hours per day	3.8	4.6	4.8	4.7	3.9	4.9	4.9	4.1	4.4	[illegible]	[illegible]
Transport hours per day	1.5	2.0	1.9	1.8	1.0	2.5	1.3	1.4	1.6	1.0	1.2
Hours worked per day	5.3	6.7	7.0	6.7	7.2	7.6	6.5	5.5	6.5	6.2	6.0
Loads per day	1.6	1.6	1.4	1.9	1.2	1.6	1.5	4.4	1.7	1.0	1.9
Services per day	410	254	333	370	407	306	410	574	854	361	31
Tons per day	9.4	9.0	12.6	14.5	12.6	9.5	[illegible]	[illegible]	14.1	[illegible]	[illegible]
On-route productivity											
Services per crew per collection hour	107.3	[illegible]	107.6	12[illegible]	104.3	62.7	84.2	138.3	200.1	[illegible]	33.3
Tons per crew per collection hour	2.5	2.0	2.6	3.1	3.3	2.0	[illegible]	1.7	[illegible]	[illegible]	[illegible]
Services per crewman per collection hour	107.3	25.2	53.4	55.2	34.9	20.9	84.2	66.6	66.7	[illegible]	[illegible]
Tons per crewman per collection hour	2.5	2.0	1.3	1.5	1.1	0.7	2.2	0.8	[illegible]	[illegible]	[illegible]
Cost efficiency**											
Total cost per home per year	$9.86	$15.60	$11.90	$11.44	$20.28	$28.80	$19.74	$26.52	$21.96	$16.64	$24.44
Total cost per ton	$8.29	$6.40	$9.53	$8.72	$12.82	$17.13	$13.48	$21.15	$14.67	$19.76	$18.41

*ACT Systems, Inc. Residential collection systems. v.1. Report summary. Environmental Protection Publication SW-97c.1. [Washington], U.S. Environmental Protection Agency, 1974. 106 p.

†RL, rear loader; SL, side loader.

‡Not available.

§Driving, riding for one-man crews.

‖Nonproductive time.

**Costs have been normalized across all 11 systems to permit intersystem comparisons; therefore, these figures do not reflect actual collection costs.

TABLE 55

1972 TRUCK PROCUREMENT COST FIGURES USED IN PRODUCTIVITY STUDY, SIDE LOADERS AND REAR LOADERS*

Capacity (cu yd)	Side loader	Rear loader
8	$14,000	
13		
16		$15,900
18		16,700
20		17,000
25	23,000	22,700
33	30,000	23,900

*ACT SYSTEMS, INC. Residential collection systems. v.1. Report summary. Environmental Protection Publication SW-97c.1. [Washington], U.S. Environmental Protection Agency, 1974. 106 p.

ance, the next section is provided to enable better comparisons. For example, an important determinant of collection time for curbside pickup is the percent of one-way storage (bags and miscellaneous) items versus cans.

The next section shows how productive the crews are on the route in terms of services per man-hour and tons per man-hour. These two variables must be considered jointly, although the amount of waste tends to be the major time determinant.

The last section shows costs on a service and tonnage basis.

In order to enable a better comparison between equipment types and crew sizes, all the basic cost figures were normalized by using the average values for the 11 cities being evaluated. For example, the procurement costs of the collection vehicles were based on average prices paid, in 1972 dollars (Table 55). The depreciation used was straight line over 5 years. Maintenance cost for the first year was 0.055 multiplied by the initial cost of the vehicle. The consumable cost was actual fuel and oil consumption multiplied by $0.17 per gallon for fuel and $0.23 per quart for engine oil. Wages in dollars per hour were $4.34 for drivers and $4.15 for collectors. Fringe benefits were 18.1 percent of wages. Personnel overhead was 13.1 percent of wages. The overtime factor was 1.5 multiplied by the hourly wage for drivers and collectors, and insurance and fees were $100 per month per vehicle.

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Appendix C
Closing Open Dumps

Governmental agencies, industry, citizens, and environmental groups should all be considered in developing a plan to eliminate a dump and to establish an acceptable substitute. The plan should provide for informing everyone about the need for closing the dump and the procedures that will be followed. The plan should also outline the funding arrangements necessary to carry out the operation and the anticipated use of the closed site. It is often more feasible to convert the dump into a sanitary landfill than to establish a new site.

INFORMATION DISSEMINATION

It is imperative that the public, industry, and municipal agencies be kept informed of activities pertaining to the dump closing. They are the source of the necessary funds and their cooperation is critical to a satisfactory solid waste disposal program. They should, therefore, be told:

- Why the dump is being closed
- How the job will be done
- What method of acceptable waste disposal will replace the dump
- What the costs are

A vigorous public information program is essential to success, and all the various techniques of information dissemination can be used to help win a favorable press. Keeping the public informed should begin when the planning starts and continue with progress reports until the dump is closed and the new disposal method is operating successfully.

DISPOSAL DURING AND AFTER CLOSING

A dump cannot be closed in a day. The rat extermination program alone normally requires up to 2 weeks, and extinguishing fires may take another week. Compacting and covering may take over 2 months, depending upon the size of the dump.

Open dumping should be stopped before rat extermination starts, and only authorized personnel should be allowed on the site during the closing operation. An approved alternative disposal site, with fixed and posted hours of operation, must be established for the former users of the dump.

RAT EXTERMINATION

Rat extermination must be given special attention when closing an active dump. At an old open dump where the food source has been exhausted, rats and insects are unlikely to be present. Where there is a nearby food source, the old dump may still be used by rats for harborage. It is necessary, therefore, to establish conclusively the absence of rats. If rats are present, an extermination program must be conducted. If the dump-closing operation is improperly conducted, the rat problem may be compounded.

Rats are potential carriers of numerous diseases; if they are not killed when a dump is closed, they may migrate in numbers to populated areas in search of food and harborage. At a minimum, this would cause unfavorable reaction to the dump closing, and the situation would worsen if there were a rise in the incidence of rat bites.

Only trained personnel should be allowed to conduct the operations since the improper use of poisons is dangerous. The work is best done by a pest control specialist or by a government rodent control expert. Assistance may be obtained from State and local health officials, pest control services, the U.S. Fish and Wildlife Service, the Center for Disease Control of the U.S. Public Health Service, or the Office of Solid Waste Management Programs.

EXTINGUISHING FIRES

Fires at dumps may be difficult and expensive to extinguish. In some cases the burning solid waste may have to be exposed and spread out, requiring the use of heavy earth-moving equipment. The operator must work very carefully to prevent injuring himself or damaging his equipment. Spreading the waste generally allows the fire to partially burn itself out, and water can then be applied to the smoldering remains. Caution must be exercised to avoid causing water pollution through use of excessive quantities of water. Fires can usually be extinguished while the rat poisoning program is underway.

COVERING THE DUMP

Immediately after the rat poisoning and fire extinguishing, the dump surface should be graded, compacted, and covered with at least 2 feet of compacted soil. In closing large dumps, the rat extermination program should be maintained while successive sections of the dump are covered. To grade, compact, and cover most dumps, large crawler dozers will be necessary. Either the trench or the area method is generally used in closing the dump.

In the trench method, wastes are spread in thin layers in an excavation, compacted, and then covered with the excavated soil (Figure 10). This achieves maximum density and minimum settlement. The cover material should be compacted to keep flies in and rats out, and it should be graded to keep surface water from ponding. The bottom of the trench should be kept above the level of high ground water.

The area method also involves spreading the wastes in thin layers, compacting it, and then covering it with a minimum of 2 feet of compacted soil (Figure 11). If the solid waste is spread over a large area, it must be consolidated and compacted to reduce the amount of settlement and cover material required. The cover material must be graded to avoid ponding of surface water.

PROTECTION OF WATER QUALITY

If the dump is in a marshland or an area where the ground water or surface waters have been contaminated, remedial action should be taken by removing the solid waste from the water or treating the water. The latter step is normally not feasible because of the difficulty in collecting and treating contaminated water. The solid waste and water can be separated by diverting the flow of water or by removing the solid waste from the watercourse. If necessary, surface streams may be relocated and the ground water level lowered, but it is often more economical to remove the solid waste from the stream using draglines.

COVER MATERIAL

Cover material should be selected according to its ability to limit the access of vectors to the solid waste, control moisture entering the fill, control the movement of gas from the decomposing waste, provide a pleasing appearance, control blowing paper, and support vegetation.

Not all soil types perform these functions equally well. While the soil is usually selected from the types available nearby, consideration needs to be given to its suitability before using it as cover material.

The depth of the cover material depends on the use planned for the closed dump and the soil type. Usually 2 feet of earth is sufficient, and it should be compacted and graded to a slope of 2 percent or greater. Proper grading is important since it prevents excessive soil erosion and ponding. Ponding tends to infiltrate and saturate the fill, resulting in water pollution.

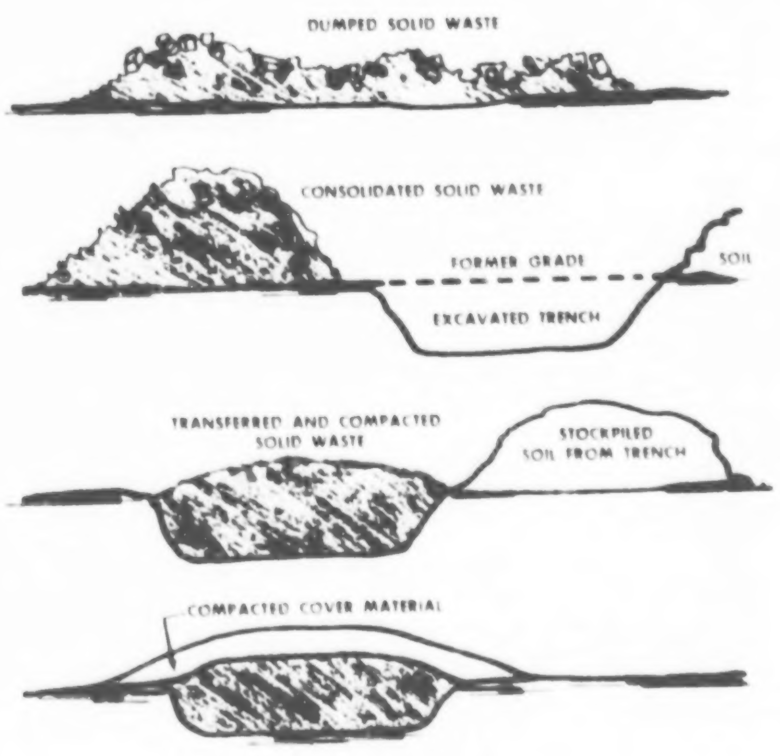

FIGURE 10. With the trench method of covering a dump, wastes are spread in a thin layer in an excavation, compacted, and then covered with the excavated soil, compacted, and graded. Source: BRUNNER, D.R., S.J. HUBBARD, D.J. KELLER, and J.L. NEWTON. Closing open dumps. Washington, U.S. Government Printing Office, 1971. 19 p.

To further reduce erosion, the area should be seeded with grass or other vegetation. Two feet of soil is usually sufficient for grass, but more is necessary for shrubs and trees. If the dump is along a lake front or the edge of a stream, riprap is often required to prevent water from eroding the edge of the cover material.

ULTIMATE USE OF CLOSED DUMP

A closed dump need not remain an unused parcel of wasteland. The site may have been changed from a ravine or gully to a relatively flat area. It is no longer unsightly since it is covered with soil and with grass and other vegetation. It is almost inevitable that uneven settlement will be extensive, and recognition of this fact should influence the ultimate use of the site.

In general, it is not advisable to construct buildings over a closed dump because it makes a poor foundation. Furthermore, gas from the decomposing waste may accumulate in explosive concentrations in or beneath buildings constructed on or adjacent to the fill. Playgrounds, golf courses, and similar recreational facilities do not normally have to support appreciable concentrated loads, and converted dumps are often used for these purposes, but they still require careful planning. Maintenance costs may be greater for recreational areas constructed on dumps than on natural ground because of excessive and irregular settling and possible cracking of the cover material.

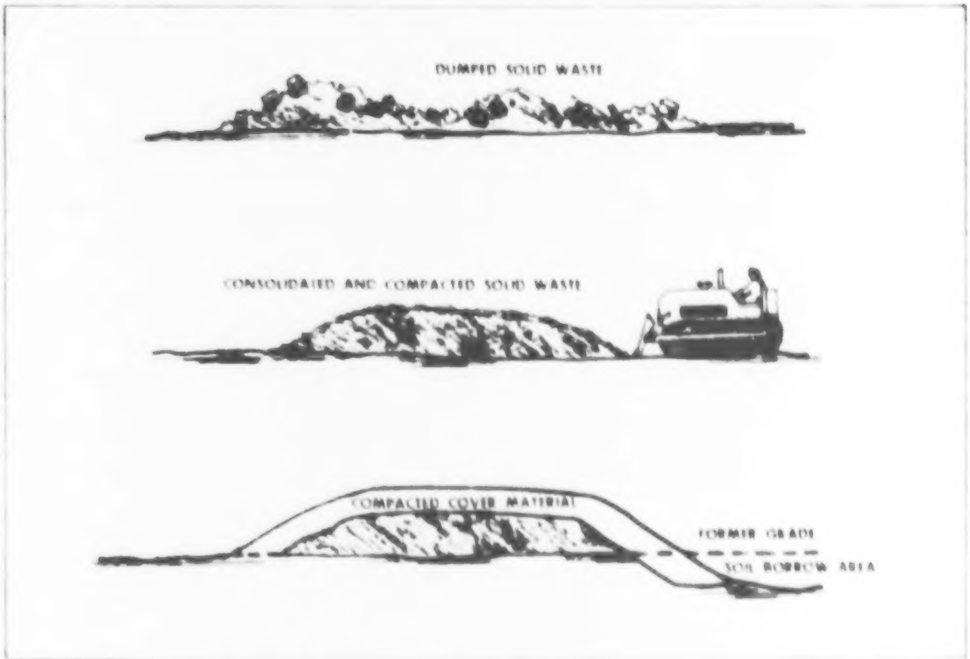

FIGURE 11.—With the area method of covering a dump, wastes are spread in thin layers, compacted, and covered with a minimum of 2 feet of compacted soil. Source: BRUNNER, D.R., S.J. HUBBARD, D.J. KELLER, and J.L. NEWTON. Closing open dumps. Washington, U.S. Government Printing Office, 1971. 19 p.

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